Northern Goshawk Population Monitoring in the Lake Tahoe Basin

Monitoring Plan Development and Protocol

FINAL REPORT

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Table of Contents

I. Executive Summary

Herein we describe a science-based monitoring program for the Northern goshawk in the Lake Tahoe Basin (LTB). This program is an early-warning system, capable of detecting a biologically significant level of change in the goshawk population, with statistical rigor. To be most meaningful, a monitoring program should include insights into the cause-and-effect relationships between stressors and anticipated population responses. Thus, the program also includes analytical tools to be able to evaluate the cause-and-effect relationships that anthropogenic stressors may have on influencing the status and trend of the goshawk population. The program is focused on territories distributed throughout the LTB.

Development of the monitoring program began with creating a conceptual model to link the key anthropogenic stressors in the LTB to their hypothesized responses by the goshawk population. We then selected several of these population responses to serve as indicators to monitor in order to determine the status and trend in the goshawk population over time. We selected goshawk territory occupancy as the primary indicator and two indicators of reproduction, nesting activity and nest productivity as secondary indicators to monitor. These indicators will be used in an occupancy-estimation analytical framework to evaluate the status and trend of the goshawk population and to evaluate the effects of stressors. A 10-year period for assessing trend was selected because this coincides with the planning cycles for USFS administrative units (e.g., LTB Management Unit). To measure the indicators we used a systematic grid of 600 ha sampling units nested within the Forest Inventory and Analysis (FIA) hexagon grid, an approach consistent with the Bioregional Monitoring Design for goshawks. Each FIA hexagon contains an area equivalent to the average male and female breeding period home range size in the LTB. We conducted a prospective power analysis to determine the optimal number of sample units to include to be able to detect a 20-30% decline in the primary indicator over a 10-year period, with ≥80% power and an alpha = 0.2. This analysis determined that 20-25 sample units would be necessary to achieve the objectives of the monitoring program. Twenty-five territories were selected from the information contained in the Lake Tahoe Basin's Management Unit's goshawk database to represent the geographic distribution of goshawk territories and the cline of stressor intensity goshawks are exposed to in the LTB. The optimal sampling frequency, considering cost and benefit, for the program is every 4-5 years, for a total of 3 sampling years over the 10-year monitoring period. The occupancy status of each sample unit will be determined using 3 surveys per sample unit, including a combination of both Dawn Acoustical and Broadcast Acoustical surveys.

The spatial and temporal characteristics, as well as the intensity of stressors (e.g., ski areas, urbanization, vegetation management) can be measured, in a GIS, for each sample unit. Stressor measurements for each sample unit can be compared with goshawk territory occupancy and reproduction data to evaluate their influence using occupancy modeling and an information-theoretic approach. The monitoring program was designed to be capable of providing short- (4-5 year) and long-term (10-year) evaluation of the status and trend in the goshawk population as well as evaluate stressor effects. Thus, it will begin to provide insight (distributional snapshot, retrospective stressor analysis) with the first year of its initiation. The estimated cost of the program is \$37,100-\$46,375 per sampling year and over its 10-year duration is \$111,300-\$139,125 for field data collection. The program is flexible and can incorporate some changes to its design (e.g., measurement of new stressors), if necessary, to accommodate changes in our understanding and budgetary realties. Any changes should be done in consultation with the authors or other researchers familiar with the statistical and sampling approaches used in this monitoring program.

II. Background & Document Objective

Background

The Northern goshawk (*Accipiter gentilis*) is a forest-dwelling raptor that breeds from low elevation (2,500 ft) ponderosa pine (*Pinus ponderosa*) forests to high elevation (>10,000 ft) true fir (*Abies* sp.), lodgepole (*Pinus contorta*) and eastside pine vegetation types in the Sierra Nevada (Grinnell and Miller 1944, Keane 1999, Hansen et al. in prep.). The northern goshawk is listed as a Sensitive Species in region 5 (Macfarlane 2007), a Species of Special Concern by the California Department of Fish and Game (CDFG 2006), a Special Status Species by the Nevada Division of Wildlife, and a Special Interest Species by the Tahoe Regional Planning Agency (TRPA). The Northern goshawk has been petitioned for listing as federally threatened three times within portions of the western U.S. under the federal Endangered Species Act. To date all listing petitions have been denied by the USFWS (e.g., USFWS 1998).

One goal of the Sierra Nevada Forest Amendment is to protect Northern goshawk populations in the Sierra Nevada (USDA 2001, 2004). To accomplish this: "Northern goshawk protected activity centers (PACs) are to be delineated surrounding all known and newly discovered breeding territories detected on National Forest System Lands" (USDA 2004). Furthermore, the draft Pathway 2007 vision statement (a planning partnership between the Tahoe Regional Planning Agency (TRPA) and Lake Tahoe Basin Management Unit (LTMBU) for all native wildlife species is that: "Environmental conditions in the Lake Tahoe Basin support healthy and sustainable native terrestrial and aquatic animal populations and vegetation communities" (TRPA 1996, Pathway 2007). To effectively manage for the protection of the goshawk population in the Lake Tahoe Region, managers need to have an increased understanding of the status and trend of the goshawk population in the LTB, an understanding of what threats to the species exist, and how they can prescribe management and mitigation alternatives to favor the goshawk's persistence. Thus, on both a Sierra Nevada wide and regional level, protection of a viable goshawk population in the Lake Tahoe region is a management objective. The development and implementation of a *monitoring* program represents the initiation of a conservation strategy to ensure the management objective, protection of the population, is being met for Northern goshawks in the LTB.

Document Objective

The objective of this document is to develop a science-based monitoring plan to support the management objective for protecting and recovering the Northern goshawk population in the LTB. Before we begin, it is important that we define monitoring as it applies here and why it is a critical component of land stewardship. Monitoring is the "measurement of environmental characteristics over an extended period of time to detect the status or trend in some aspect of environmental quality" (Suter 1993, p. 505). Monitoring is conducted at regular intervals to assess both the current status and the time trend in ecological resources (e.g., specific ecosystems [wet meadows], ecological processes [photosynthesis], individual species [Northern goshawks], and habitat elements [large snags]; Noon 2003). Monitoring is a dynamic process because human behavior and continuing population growth lead to ongoing environmental changes with unexpected and 'surprise' ecological events as unavoidable consequences. As a result, responsible stewardship requires continual assessment of the status and trend for species of concern and the effect of human behavior (Noon 2003). The most common reason to monitor a species is to detect differences in its indicator value(s) among locations at a given moment in time (status), and/or changes in values across time at a given location (trend). An indicator is a carefully chosen attribute of the species (e.g., presence/absence, population size) to be measured. Changes in the values of an indicator of a species' status or trend are useful and relevant to management as they provide an assessment of management success or provide an early warning system before irreversible loss (e.g., regional extirpation) has occurred (Noon 2003). A monitoring program is developed to detect specific amounts of change that are biologically important to a species' population persistence and thus provide specific trigger points at which managers must respond to detrimental levels of change. A monitoring program combines the objectives of statistical rigor with sampling efficiency, to develop a program that provides a reliable answer at a reasonable cost.

To achieve the objective of this document, we will first develop a conceptual framework for designing the monitoring program. Second we will review and synthesize relevant historical and contemporary information on the distribution, status, and trend of goshawks in the LTB and determine whether a reference condition can be established. The third step will be to identify key threats (stressors) to goshawks in the LTB and use these to help identify the appropriate indicators to monitor. The fourth step will be to design a monitoring program to determine the status and trend of the selected indicator(s) that balances statistical rigor and cost. And the final step will be to provide all the necessary tools (e.g., data collection and analysis protocols) to be able to conduct the monitoring program.

III. Relationships to other Inventory and Monitoring Plans

Northern Goshawk Bioregional Monitoring

In 2006 the Northern Goshawk Inventory and Monitoring Technical Guide was produced to provide guidance for the U.S. Department of Agriculture Forest Service and interested parties for consistent methods for conducting inventory and monitoring of goshawks (Woodbridge and Hargis 2006). This document provides guidance on establishing a monitoring design and survey methodologies at a bioregional scale. The LTB falls within the Cascades-Sierra bioregion which extends from California to the Canadian border in Washington. Monitoring at this scale requires a regional coordinator and the cooperation of the many National Forests included in each bioregion that support Northern goshawks. Thus, from a design perspective the bioregional approach is too broad to achieve the monitoring goals for a single management unit like the LTB. However, by designing the monitoring program to be as compatible as possible with the bioregional survey methods, the data generated from the LTB will be useful both locally and for the bioregional monitoring program. We will seek to maintain as much consistency as possible between the bioregional approach and the one developed herein to ensure future comparability of data.

Multiple Species Inventory and Monitoring

The MSIM program provides a framework for collecting presence-absence data on a variety of terrestrial vertebrate species, including goshawks, over large areas. The LTB goshawk monitoring program is compatible with respect to the use of the FIA grid system.

IV. Review of Existing Information on the Status and Distribution of Northern Goshawks in the LTB

Historical Distribution of Northern Goshawks in the Lake Tahoe Basin

Historical records for goshawks in the LTB are scarce. Grinnell and Miller (1944) reported that they occupy coniferous forest (especially, red fir [*Abies magnifica*] and lodgepole pine) up to 9,000 feet and they list one nesting record in the 'vicinity of Lake Tahoe' in 1922. Ray (1926) reported that this locality supported nesting by the same pair during 4 of the next 4 years the site was revisited. Ray (1926) also listed the following locations for goshawk observations: adult, upper Velma Lake, July 1923; head of Barton creek, nesting 'for a number of years'; near Tahoe City, August 1919, south of Tahoe Tavern, October 1924-1925, adult with fledged young near the head of General creek, August 1919, adult, edge of Rowands marsh, October 1925. The scarcity of historical records from the Lake Tahoe region can be attributed, in part, to the secretive nature of goshawks and the difficulty of detecting and accurately identifying them. These records at best indicate that goshawks historically occurred and bred in the Lake Tahoe region, but do not provide enough information to establish a historical reference condition of their distribution.

Contemporary Research Findings & Distribution of Northern Goshawks in the Lake Tahoe Basin

From 1991-1995, Keane (1999) studied the migration status, annual home ranges, nest-site habitat characteristics, and the association of biotic and abiotic factors with annual variation in reproduction of goshawks in the LTB. Keane (1999) estimated that 17-21 goshawk territories are possible in the LTB, based on 12-15 goshawk territories that were known to exist in the LTB at that time and with the additional 5-6 territories based on the distribution of known territories and suitable habitat. Goshawks were found to be year-round residents in the LTB and distributed throughout the Lake Tahoe Basin, breeding from lake level to tree-line. Home ranges differed according to season, with both sexes using smaller areas during the breeding periods (95% adaptive kernel means = 2698 ha and 2016 ha for males and female, respectively) than non-breeding periods (95% adaptive kernel means = 9379 ha and 5555 ha for males and female, respectively).

Goshawk nest site habitat was best predicted by the presence of dense canopy cover (>5m height), live trees >100 cm dbh, and low amounts of shrub/sapling cover. Goshawk reproduction was greatest in years with abundant late-winter/early-spring Douglas squirrel (*Tamaisciurus douglasii*) populations, following high cone crop production from the previous autumn, and mild late-winter/early-spring temperatures. On an annual basis, reproduction, represented by both the number of active nests and successful nests (fledging >1 young), varies significantly. Over a 4-year period Keane (1999) monitored 14-21 occupied territories annually and during this period active nests and successful nests ranged from 47-100% and 37-82% annually, respectively. This work provides a tremendous resource to aid the management and conservation of goshawks in the LTB, by providing critical information on the ecology of goshawks, their space use, nesting habitat requirements, and linkages of key prey populations to reproduction.

Young and Morrison (2007) assessed the historical and contemporary occurrence and status of 36 goshawk territories in the Lake Tahoe Basin in 2004-2005. They found that frequency of territory occupancy was a good indicator of habitat quality. Reproductive success in frequently occupied territories was significantly higher than infrequently occupied territories (mean fledglings per nest 0.72 [0.67] and 0.17 [0.51], respectively). Of the 23 territories they considered, 8 were frequently occupied (>75%), 7 moderately occupied (40-75%), and 8 infrequently occupied (<40%) during surveys conducted from 1977-2005. However, their analysis did not incorporate any consideration of detection probability for the different survey protocols used or varying number of surveys conducted in each territory during each year. Most annual survey efforts during these retrospective surveys used nest checks or broadcast surveys and typically included <3 surveys per year, likely resulting in detection probabilities <0.9 (Keane and Woodbridge unpubl. data). The consequence of this is that 'occupied' territories are more likely to contain active nests and 'unoccupied' represent both truly unoccupied territories and a number of occupied territories without nesting activity (false negatives). Due to the fact that nesting goshawks are more easily detected than non-nesting goshawks occupying territories, the analysis is somewhat biased and likely better represents characteristics of where goshawks are and are not nesting more consistently rather than where occupancy is more or less constant.

With the above caveat stated, Young and Morrison (2007) found that frequently occupied territories had lower amounts of anthropogenic disturbance, best characterized by the amount and use levels on local roads and highways near nests, and contained more elements of mesic, late-successional forests in their cores and non-disturbance zones (800 m radius of most recently active nest) than infrequently occupied territories. Frequently occupied territories had higher mean dbhs for live trees, more coarse woody debris in nest cores and had more mature stands in red fir and mixed conifer types within 800m of the nest than infrequently occupied territories. Multi-variate analysis was not conducted, so a relative ranking of the importance of anthropogenic disturbance versus habitat quality was not made. However, these stressors represent two types of stressor action, pulse and press. Where anthropogenic disturbance is a pulse event that largely occurs during the incubation and nesting season and increases through the nestling period. Habitat quality is comparatively constant, slowly changing annually.

We compiled the results of goshawk surveys conducted by the LTBMU and cooperators (e.g., CA state parks, Nevada Division of Wildlife, private consultants). Records span a period of 30 years, from 1977 to 2007. During that period, 92 nest and 400 detection (auditory or visual observation of a goshawk, or recent sign: plucking post, molted feather) records were compiled in LTBMU's goshawk database. We used the distribution of these records to indicate a contemporary reference condition for distribution (Figure 1). It should not be interpreted that all locations with records are occupied during any one year, but merely to demonstrate the distributional pattern over the entire 30 years. Goshawk records from the last 30 years occur throughout the LTB, but are particularly concentrated in the mid and lower elevations (Figure 1). Records are particularly sparse on the west-central and southwest portions of the LTB, due perhaps to the lower overall habitat suitability in this region (Dunk et al. in prep.), as well as lack of survey effort.

We assessed whether the goshawk survey efforts and their results could be used to determine either occupancy rates for territories or status and trend for the LTB goshawk population. Records of survey locations are only documented from the late 1990s through 2007. Survey methodology has changed during this period, most significantly in 2001 when dawn acoustic surveys were added, resulting in significantly higher rates of goshawk detections. From 2001 through 2007, both annual survey effort and the locations surveyed varied, creating further challenges to using this information to determine patterns of occupancy, status, and trend. The number of active territories found increased from a low of 3-4 in 1997 to a high of 26 in 2006. However, due to the inconsistencies in survey methodology and survey locations during this period it cannot be determined whether this pattern represents the improving ability to find and determine active territories or a real population trend.

We also evaluated Young and Morrison's (2007) 2-year survey effort for: (1) potential as an initial monitoring period (2) to provide estimates of key parameters for the power analysis. Of the 39 territories, Young and Morrison (2007) included 37 territories in their 2-year study. Two types of survey efforts were used, dawn acoustic and broadcast acoustic surveys following the USDA (2002) protocol. Survey effort was not equivalent among territories within or between years. More detrimental than unequal sampling effort among years was the cessation of repeat surveys once a detection occurred. While this is a logical approach when considering survey cost efficiency, for data analysis and determining detection probability it results in bias. Specifically, it over-represents unsuccessful surveys and underepresents successful surveys. Thus, detection probability is underestimated and the estimate of occupancy is overestimated due to it being negatively correlated with the bias in detection probability. In this case, the two annual estimates of occupancy were highly different, largely due to the variation in surveys conducted, not in the effectiveness of either survey technique (Table 1). This highlights the importance of repeat sampling in territories after detections have been made in order to demonstrate the repeatability of the detection outcome for data analysis and accurate parameter estimation, especially when sample sizes are small (e.g., <50).

Table 1. Detection probability and occupancy estimates using Program PRESENCE (Version 2.0, McKenzie and Hines 2006) for Young and Morrison's (2007) survey histories for Northern goshawks in the Lake Tahoe Basin from 2004-2005. Estimates are from the top model considered, constant p, constant ψ.

Year	Detection probability (SE)	Occupancy ψ (SE)	Observed ψ
2004	0.627 (0.099)	0.498 (0.098)	0.52
2005	0.358 (0.053)	1.0 (0.00)	0.74

While these previous survey efforts may not be capable of determining goshawk population trend, they provide a tremendous source of information on the population. This information has benefited other management objectives (e.g., mitigating effects of projects, providing nest tree buffers for activities during nesting) and will be the foundation of the monitoring plan developed herein.

From the review of contemporary information, we conclude the following:

1. goshawks are still relatively well distributed in the LTB.
2. there are insufficient data to suggest a population trend.
3. anthropogenic stressors are affecting reproduction; some can be avoided (e.g., tree felling near active goshawk nests) or monitored.

Due to the goshawks being relatively well distributed in the LTB and no evidence to support a negative population trend, the management objective should be to retain the current distribution of the goshawk population throughout its contemporary distribution. Thus, the monitoring plan will be developed to support this management objective by being capable of detecting a significant negative change of status and trend over time.

V. Development of a Conceptual Monitoring Framework

In the LTB, the management objective is to protect and restore the goshawk population in the region. **Because our review of the historical and contemporary information on the distribution of goshawks leads to the conclusion that goshawks are still relatively well distributed in the LTB, the emphasis of the monitoring program is on retaining the contemporary distribution of the goshawk population throughout its contemporary distribution (reference condition; Figure 1).** To ascertain compliance with this management goal will require the initiation of a monitoring program capable of detecting biologically meaningful levels of change in the goshawk population. If the monitoring program demonstrates either a lack of significant change or a positive change in the goshawk population, it supports compliance with the management goal. If the monitoring program demonstrates a significant negative change in the goshawk population, it should trigger specific changes in management practices.

The task of identifying a meaningful change requires some understanding of the levels of change caused by natural intrinsic factors (e.g., severe winters, prey population cycles) versus human-caused extrinsic factors (e.g., disturbance during nesting). Both can have population level affects, but typically species have had the time to evolve and cope with the natural variation in intrinsic factors while they are not necessarily able to incorporate the additive variation from human-caused extrinsic factors. Not all extrinsic factors may be detrimental to goshawk populations, those that are, or are hypothesized to be, are hereafter referred to as stressors.

Stressor effects are evaluated in the context of induced changes to one or more indicators (Noon 2003). Not all stressors are known nor are their relative magnitudes of effects understood *a priori*. In the case of monitoring the goshawk population in the LTB, there are a number of potential stressors that affect different portions of the LTB to different degrees. Thus, stressor affects may be working independently in one area or synergistically in another, and potentially in both spatial and temporal scales. All monitoring programs need to acknowledge the difficulties of implicating one or more stressors as the cause of a change in an indicator. However, to embark on a monitoring program that does not include the evaluation of potential stressor effects misses an important opportunity. The consequence of missing this opportunity would be embracing a monitoring program to detect change, but with no way to indicate what is causing the change.

A monitoring program can be designed to evaluate indicator-stressor relationships by being retrospective or prospective. Retrospective monitoring or effects-oriented monitoring seeks to find stressor effects after they have occurred by detecting changes in the condition of a species' population (NRC 1995). In contrast, prospective or stress-oriented monitoring attempts to detect the known or suspected cause of an undesirable population effect, before the effect has a chance to become serious (Figure 2). Thus, prospective monitoring, unlike retrospective monitoring, assumes prior knowledge of cause-effect relationships between stressors and indicators (Thornton et al 1994). However, cause-effect relationships for wildlife populations are seldom known with certainty and are usually only suspected. In this case, a hybrid approach is necessary that emphasizes simultaneous indicator and stressor measurement, and modeling the relationships between stressor actions, change in state of indicator, and subsequent population effects (Noon 2003).

The hybrid approach is the best design for a monitoring program for goshawks in the LTB and is the approach used for effectiveness monitoring of the Northwest Forest Plan (USDA et al. 1993). The first step in the design process for this approach is to develop a list of the hypothesized stressors to the goshawk population in the LTB (see section VI (Identification of Stressors & Selection of Indicators). A conceptual model then identifies the scale-specific linkages between stressors and the hypothesized population effects. Indicators that are predictive of the anticipated changes in population condition are then selected for measurement (NRC 1995, 2000, Noon 2003).

Adding further complexity to the interpretation of monitoring results is that when a monitoring program is initiated it begins with the effects of past stressors (e.g., logging and ski resort development) and over the course of additional monitoring seasons incorporates the cummulative effects of these past and additional future stressors (e.g., fuels treatments; Figure 3). Thus the initial monitoring period provides an opportunity to retrospectively evaluate past management effects by testing hypotheses representing their suspected effects on population indicators. The knowledge gained from this retrospective analysis can be used to better develop stressor-indicator relationships that can be validated with future monitoring data (Figure 5). Thus, the value of using the initial monitoring period to learn from past management, through retrospective analysis, should not be underestimated. Young and Morrison (2007) identified human activity as an anthropogenic stressor for presence and nesting success and this should continue to be monitored. However, their analysis also found differences between the forest structure in the nest stands and nearby areas, suggesting that habitat structure and composition also plays a role in goshawk occupancy and reproduction. This highlights the need for a multivariate approach for future analysis such that anthropogenic stressors can be tested against and combined with habitat characteristics to determine which factors are having the most influence on goshawk occupancy and reproduction. In section VII, Data Collection and Analysis, we will describe such an approach to implement after the first data collection season.

VI. Identification of Stressors and Selection of Indicators of Population Status and Change

A stressor is a factor that adversely affects individuals, populations, habitat, and/or prey. While stressors can include those from both anthropogenic (extrinsic) and non-anthropogenic (intrinsic) sources, we focus only on extrinsic stressors, those from anthropogenic sources. Extrinsic stressors are the results of human action and therefore can be altered if necessary through changing of management practices. There are a number of stressors in the LTB that may have had historical and/or contemporary negative effects on the goshawk population. Historical stressors may have caused declines or local extirpations which may or may not have had time to be reversed since these activities ceased. Historical stressors to Northern goshawks in the LTB may include rodent poisoning, livestock grazing, logging, fire suppression, and urban development (Lindstrom et al. 2000). Potential contemporary stressors include continued urbanization, motorized and non-motorized recreation on existing and new trails and roads, vegetation management (e.g., fuels treatments), fire management, and the development of and recreation related activities at ski resorts (Squires and Kennedy 2006). The current status and condition of the goshawk population will be a product of any lingering effects of past stressors (e.g., areas still not recolonized due to the lack of regeneration of suitable nesting structures removed by logging) and its current responses to contemporary stressors. We will provide a brief discussion of the 5 stressors we hypothesize to be the most detrimental to the goshawk population in the LTB.

Urbanization

Urbanization has a number of known and potential effects on goshawks. The conversion of forest habitat to urban uses (e.g., roads, houses) is a direct loss of habitat and the fragmentation of remnant habitat in the vicinity. Indirect effects are the high number of humans present in forested habitats and roads along the urban fringe that can disturb foraging and nesting goshawks, increased management (e.g., fuels reduction), high densities of competitors (e.g., coyotes) supported by food subsidies (e.g., garbage and other sources) that can reduce natural food resources in the vicinity of urbanization.

Ski Area Development & Operation

There are approximately 25 ski resorts in the Sierra Nevada mountains, nearly all of which occur within the range of the Northern goshawk. The Lake Tahoe region includes about half of these resorts, constituting the highest density of resorts in the Sierra Nevada and one of the highest in North America. The development of ski resorts involves the loss and fragmentation of forest habitat through the removal of trees for creating ski runs, creation of roads, and building of infrastructure (e.g., lifts, buildings). The operation of ski resorts includes the continued compaction of snow and presence of high densities of humans. These factors can have negative effects on goshawks both directly (e.g., avoidance of these areas due to too much disturbance) and indirectly (e.g., snow compaction and forest fragmentation facilitating increased competition with coyotes

[*Canis latrans*], red-tailed hawks [*Buteo jamiacensis*] and great horned owls [*Bubo virginianus*], respectively).

Vegetation Management

We use vegetation management here to define any management activity (e.g., timber harvest, hazard tree removal, fuels treatment, prescribed fire) that alters goshawk habitat. Vegetation management can have both positive and negative effects, which can either have short or long-term temporal impacts. A short-term negative effect of vegetation management is the reduction in canopy cover, and reduced suitability of the stand for nesting. However, canopy cover can regenerate relatively quickly. Vegetation management can also affect prey. For example, Bull and Blunton (1999) found that fuels reduction treatments in lodgepole pine (*Pinus contorta*) and mixed conifer stands in northeastern Oregon reduced key prey species, including snowshoe hare (*Lepus americanus*) and red squirrels (*Tamaisciurus hudsonicus*) in all and some stand treatment types, respectively. A critical long-term negative effect is the removal of large-diameter conifers, which provide nesting locations and cone crops for key prey species, and take more than a century to regenerate. A positive short and long term effect would be to thin stands currently too dense to permit goshawk foraging, while maintaining the largest diameter trees for producing cones props to support prey populations and to provide potential nesting locations.

Young and Morrison (2007) found that fuels treatments that occurred within 800m of active nest sites during the 'limited operations period', likely caused the direct mortality and abandonment of 2 nests during their 2-year study. This was the result of inadequate survey prior to conducting activities. Managers cannot allow this type of direct mortality and reduction in reproduction to occur when it can be avoided. This indicates that vegetation management activities must be tracked to avoid such unfortunate occurrences. Furthermore, testing for less direct effects from this stressor in territories clearly is warranted. Specifically, both the treatment intensity (e.g., percent of canopy cover remaining, density of large downed logs remaining) and spatial extent (e.g., percent of territory treated) should be compared to goshawk occupancy and reproduction.

Motorized Recreation

Motorized recreation, which includes off-highway vehicles (OHVs; 4x4s, quads, dirt bikes) and on-snow vehicles (OSVs; snowmobiles), have been considered potential stressors due to the noise, speed, and locations where they can travel. Young and Morrison (2007) found negative relationships between human activity, indexed partially using vehicle passage rates on roads, and territory occupancy and reproduction. It is unclear whether the activity on the roads or the other features correlated with more frequently used roads (e.g., more human presence, increased habitat degradation, increased fire suppression). However, an experimental study of the effects of motorized recreation on goshawks has yet to find negative effects caused by this potential stressor on reproduction or survival (J. Dunk pers. comm.). In peak seasons of OHV/OSV use, goshawks are naturally active during the same periods of the day that OHV/OSV users were, increasing the potential for encounters. Unless OHV/OSV use increases above the levels observed in this study, motorized recreation will likely remain a non- or minor stressor for goshawks. Winter can be a very hard season for Goshawks, disturbance can be detrimental.

Non-motorized Recreation

Human presence has the potential to disturb goshawks, especially during the nesting period. Keane (1999) reported human disturbance at three nesting locations during a 4-year period in the LTB. These cases involved harassment and potentially direct mortality, from humans at goshawk nests. Goshawks can be very aggressive in the defense of their nests, and if frequently disturbed this can result in high energy expenditures for nest defense with potentially detrimental affects to nesting success. If nests are near roads or trails, conflict between goshawks and humans can arise for use of the same areas. In the cases documented by Keane (1999), human disturbance likely contributed to nest failure and may affect the future use of suitable nesting stands.

Linking Stressors to Goshawk Population Effects

The selection of indicators that reflect a species response to extrinsic stressors requires a well-developed conceptual model of the ecological system being managed (Manley et al. 2000). The foundation of this cause and effect conceptual model is found in Figure 3. The ideal case would be to build a conceptual model from a foundation of knowledge, based on rigorous investigation on how a species responds to individual stressors of interest. In practice, this type of information is usually either lacking entirely or only available from other geographic portions of a species' range. The latter situation applies to goshawks in the LTB. Using existing information and hypothesized relationships we developed a conceptual model to link the 5 extrinsic stressors to likely responses by the goshawk population in the LTB. The first step, was to identify the specific ways in which each stressor affects relevant ecosystem functions. The second step was to link these specific stresses to their ecological consequence; how they result in direct or indirect changes to the system. The third step was to link these stressor induced ecological consequences to goshawk population responses. It should be clear that this conceptual model (Figure 4) represents a working hypothesis on how stressors affect the goshawk population in the LTB. The resulting goshawk population responses are listed in relative order of severity (Figure 4). These responses are related, such that as lower severity effects are felt by a larger proportion of the goshawk population, they will begin to cause more severe effects (e.g., reduction in distribution and decreased population viability). The strengths of the linkages and the magnitude of their effects will depend on their spatial extent (e.g., how much area is affected), intensity (e.g., degree of stressor effect), temporal attributes (e.g., rate of stress), and synergistic effects when other stressors are also present.

Indicator Selection

In the development of monitoring plans, selection of indicator(s) that directly relate to the monitoring objective are required to provide the most useful inferences. As mentioned earlier, the management objective is to protect the goshawk population within its contemporary range in the LTB. Following the management objective, the monitoring objective is to monitor the status and trend in the goshawk population throughout its contemporary distribution in the LTB (Figure 1).

On the basis of the conceptual model and consideration of the management objectives for goshawks in the LTB, we identify the following candidate indicators: (1) territory occupancy, (2) nesting activity, and (3) nesting productivity. Territory occupancy is defined as the detection of one or more individuals, in a territory during the breeding season. Detections are verifiable visual observations, heard auditory calls, or the presence of recent goshawk molts (feathers) in the survey area. Nesting activity is defined as the presence of an incubating adult, ≥1 nestlings, or if these are missed or the nest location is not known, the presence of ≥1 fledglings surviving to the branching or fledging stage in the survey area can confirm nesting activity when they are found on or before the 15th of August. Due to the difficulty of accurately determining the number of fledglings produced per nest (Woodbridge and Hargis 2006), a surrogate for nesting productivity will be used. To estimate nesting productivity, the number of large nestlings (24-30 days old) present will be used to as a surrogate for fledging rate. Population viability assessment and survivorship are more difficult and costly to estimate and do not readily fit into a monitoring framework.

Primary Indicators

One of the most detrimental population responses to stress is to cause a territory within the historical range to no longer be occupied by goshawks. This can occur directly when the stressor(s) results in mortality of the individual(s) that occupied the site or indirectly when the stressor(s) causes the individual to move elsewhere to find a suitable territory. This results in a reduction in the size of the breeding population and in the size of the geographic range of the breeding population. Territory occupancy during the breeding period of the year indicates that the site is attractive as a territory for at least one or a pair of goshawks. Territory occupancy is the primary indicator in this monitoring plan.

The territory occupancy approach is designed to answer the monitoring question: 'What is the status of the overall goshawk population in the LTB?' by identifying the proportion of territories that are occupied and identifying the spatial distribution of territory occupancy.

Comparing the proportion of territories occupied between two or more time periods will determine whether a decline has occurred. Investigation of the specific locations where changes have occurred will help address the cause of the decline. Furthermore, patterns of territory occupancy can be specifically compared to the pattern and intensity of stressors. The initial sampling period offers both an opportunity to assess the status of goshawk territory occupancy and –to the extent stressors can be quantified--how territory occupancy differs relative to areas with and without stressor effects. Subsequent sampling periods will primarily provide direct comparison of both overall and site-specific territory occupancy status and secondarily will provide insight into how occupancy changes relative to changes in the magnitude of stressor intensity or spatial extent where they occur.

Secondary Indicators

The secondary indicators include two measures of reproduction, nesting activity and nesting productivity, that are included to provide additional tools to investigate specific hypotheses about how stressor affect goshawk reproduction. Secondary indicators require the identification of nest locations and their outcome (successful, how many young fledged) for each year.

Identification of Biologically Significant Indicator Thresholds

We propose a monitoring program capable of detecting a 20-30% decline in goshawk territory occupancy over a 10-year period. Because declines can progress slowly (e.g., a small annual decline) or rapidly, we will provide a design and analytical tools capable of detecting both types of declines. A slow decline requires the determination of the trend of a population over a significant period of time and requires more effort to detect than a rapid decline. Over a 10-year period, a 20% decline in the index is equivalent to a 2.2% annual rate of decline. Detecting this level of change over a shorter time period (e.g., say over 2 years) requires less effort. A 20-30% decline represents a level of change that is significant to a population and that we assume excludes natural fluctuations that may occur due to annual variation (e.g., effect of winter severity on survival). This threshold (20%) also matches the minimum standards for the National Inventory and Monitoring Framework (April 3, 2000, http://www.fs.fed.us/emc/rig/iim) and matches the design for the Bioregional monitoring plan for goshawks (Woodbridge and Hargis 2006).

The approach to monitoring goshawk reproduction is more difficult than monitoring territory occupancy due to the high amount of annual variation in goshawk reproduction (annual number of active and successful nests) and the small number of territories with nest activity in most years. These two factors combine to make detection of statistically significant levels of change challenging. The design for this analysis would be to collect reproductive histories for multiple years for each territory and then look either for a trend or whether stressors are affecting reproduction. The number of years required to detect anthropogenic effects of reproduction depends on the severity of the effect. Extreme effects, either positive or negative are easier to detect than subtle ones. Thus, as the dataset on reproduction grows, so will the ability for it to detect smaller levels of change. Given the importance that reproduction plays in the health of the goshawk population and the fact that the territory occupancy survey protocol involves surveying at known nests, reproductive indicators can be collected without too much additional effort. Furthermore, other management objectives (e.g., placing seasonal restrictions on human activity in close proximity to active nests) require the determination of goshawk nest site activity and will benefit from this monitoring.

Goshawk reproduction is largely controlled by natural factors (e.g., winter-spring weather severity and prey populations). These factors vary annually, but should fluctuate similarly within all goshawk territories in the LTB. Thus, instead of attempting to detect a mean level of or change in reproduction over a given time period, the question of interest should be are stressors having a significant effect of goshawk reproduction after accounting for natural levels of annual variation. In this approach, the unit of measurement is the reproductive outcome (active nest, nest productivity) for occupied territories through time. Year is used as a covariate to account for the annual variation in winter/spring weather severity and prey populations. Stressors are also used as covariates, to assess their contribution, positive or negative, to goshawk reproduction. Because we have no prior data to estimate the likely levels of variation and parameter effects (e.g., reproductive persistence, the likelihood that goshawks breed in successive years regardless of the conditions), development of a power analysis would likely not be very accurate.

VII. Monitoring Approach Development

Sampling Design

Identification of Potential Territories

Our approach begins by overlaying on the LTB a grid of hexagonal cells (hereafter called hexes), each with an area of sufficient size to assume independence between adjacent hexes with respect to breeding season goshawk territories. We compared the hexes from the FIA program (2404 hectares) to the estimates of breeding season home ranges estimated by Keane (1999). Breeding season adult males (n = 11) and adult females (n = 7) had 95% adaptive kernel home ranges of 2698 (SD = 1043) and 2016 ha (SD = 1690), respectively. FIA hexes represent 84%-112% of the mean and 31%-138% of the 95% confidence intervals of male and female breeding season home ranges, respectively (Table 2). The FIA hexes represent a good approximation of the mean breeding season home range for Goshawks in LTB.

We next evaluated the independence of the FIA hexes by determining how many hexes had >1 nest in any year using the LTBMU's goshawk survey database. Of the 24 FIA hexes with confirmed goshawk nests, only 3 (14%) had >1 nest during a single year. We further investigated these by overlaying Lyon's (unpubl. data) locally developed goshawk nesting habitat suitability coverage on all hexes. Two of these FIA hexes (07, 56) had the largest amounts of high and marginal habitat combined compared to all other grid cells and the other cell (52) had patches of high and marginal scattered on opposite edges of the cell. These are the two cases in which it would be expected that the likelihood for >1 nesting pair per hex may exist. Furthermore, we also considered how many known territories showed nesting in >1 FIA hex. This occurred only in 3 territories

(Burton Creek, Chamonix, and Mid Saxon). For hexes with similar characteristics, sampling effort may need to be increased to be able to detect >1 nest per year. The FIA hexes represent a good approximation of the mean breeding season home range for Goshawks in LTB and thus should provide a reasonable approach for meeting the assumption of independence. Furthermore, use of the FIA hexagonal grid will meet our secondary objective, to maintain consistency between the design of the LTB and Bioregional monitoring programs.

Table 2. 95% adaptive kernel breeding season home ranges for Northern Goshawks in the LTB (Keane 1999) and their relationship to the area contained in FIA hexagonal sample units (2404 hectares).

	Mean Breeding Season Home Range (SE)	95% Confidence Interval for Breeding Season Home Range	Percent of FIA Hex	
			Mean	95% C.I.
Male	2698 (314)	2070 - 3326	112%	86-138%
Female	2016 (638)	740 - 3292	84%	31-137%

We used a 2-step process to determine the number of FIA hexes to be included in the monitoring program. First, we eliminated all hexes that had <20% of their area within the LTB administrative boundary or that had >80% of water. Second, we used the goshawk habitat suitability model version 2 (Lyon unpubl. data) to remove any hexes with <5% of high and marginal habitat combined. After these two steps, 45 hexagonal cells remained (Figure 5).

The final step was to identify which hexes had previous information on goshawk occurrence during the breeding season. We used the LTB's goshawk database to determined which hexes nests or detections during the breeding season from 1977-2007. Twenty-one (47%) hexes had a goshawk nest in at least one year and an additional 15 (33%) have had goshawk detections during the breeding season in at least one year from 1977-2007 (Figure 5). Thus, based on the results of survey effort from 1977-2007, a total of 36 hexes have the potential to support goshawk territories. These 36 hexes will be further considered for inclusion in the goshawk monitoring program.

Sampling within FIA Hexes

The next step is to determine how to sample in each selected FIA hex to determine territory occupancy. It would not be logistically feasible to sample the entire extent of each FIA hex, so a second level of stratification is needed. To accomplish this we have adopted the sampling design of Woodbridge and Hargis (2006) in which a network of 600 ha squares will be nested within the FIA hexagonal grid system (Figure 6). These 600 ha squares will be the sample unit in which territory occupancy will be assessed and compared for status and trend through time. Each FIA hex contains 4 sample units.

In most FIA hexes, the sample unit with either historical nesting information or the highest amount suitable nesting habitat will be surveyed in order to determine goshawk territory occupancy. In the few FIA cells where >1 nest is a potential, 2 or more sample units will be selected to be surveyed. The 600 ha sample units are small enough to be effectively surveyed and meet the assumption of independence (no more than 1 territory per sample unit).

The next step was to develop a method to rank the survey priority for each sample unit. To accomplish this we used the combination of existing goshawk information and identified the amount of suitable habitat found in sample units where goshawks have nested from 19977-2007. To determine the presence contemporary goshawk occupancy records and habitat suitability for each sample unit, we overlayed nest and breeding season detection records from the LTB's goshawk database and habitat suitability from Lyon (unpubl. data) on the sample unit coverage.

Thirty-three sample units have ≥1 nest record (Figure 7) and 84 sample units have ≥1 detection (Figure 8). Goshawks nested in sample units with significantly more high and marginal habitat than sample units without goshawk nest records. We used the 95% confidence interval around the mean High + Marginal habitat at sample units with goshawk nests (95% C.I. = 246-365 ha) to provide a nesting habitat threshold (>245 ha of High + Marginal) to be able to rank all sample units without nest records. We developed a 3-level survey priority ranking system: (Primary) nest record in or since 2000 (Secondary) nest record prior to 2000 (Tertiary) Combination of ≥1 detection and >245 ha of High + Marginal habitat. All other sample units are considered low priority due to the absence of nesting records or the combination of detections and a suitable amount of habitat for nesting. Thirty-five sample units are ranked as Primary, 13 as Secondary, and 11 as Tertiary (Figure 9). Thirty-three FIA hexes have ≥1 Primary, Secondary, or Tertiary sample unit. Only sample units ranked Primary, Secondary, or Tertiary will be considered for inclusion into the monitoring program.

Sampling Method

To determine sample unit occupancy the Territory Monitoring Approach (p. 3-23, Woodbridge and Hargis 2006) will be used to maximize the use of existing information on the nest stands for multiple territories and to increase monitoring efficiency. All selected sample units will receive a minimum of 3 surveys during each year of monitoring. The sequence of survey types will vary depending on the information available for each sample unit. For sample units with *known nesting locations,* which include used nests or suspected nest stands, the survey sequence consists of a Dawn Acoustical survey, and 2 follow up surveys to check nest status or conduct Intensive Nest Search Surveys or Broadcast Acoustical surveys if the nests appear inactive (Figure 10). For territories with *unknown nesting locations*, the survey sequence consists of Broadcast Acoustical surveys and Intensive Nest Search Surveys to locate the nest location/stand once a detection occurs (Figure 10). We adopt the overall guidelines for Dawn Acoustical, Intensive Nest Search Surveys, and Broadcast Survey protocols described by

Woodbridge and Hargis (2006). In figure 10 we provide a decision tree to guide the execution of the field protocol depending on: (1) the current nest location information known from the territory (2) survey-specific detection outcomes.

Dawn Acoustical Surveys

This survey protocol is used to detect the courtship vocalization and flight displays of territorial goshawks near their nest locations. To be used it requires that the nest location or stand be known from recent (≤3 years) surveys. This protocol consists of establishing listening stations in close proximity (<200 m) to the known nest or in the known nest stand and conducting 1 ½ hour listening periods at dawn during the early breeding season (Dewey et al. 2003, Penteriani 1999). These surveys have a very high probability (90-100%) of detecting goshawks if they are present and only require 2 listening sessions (Penteriani 1999, Keane and Woodbridge 2002, Dewey et al. 2003). Specific details of the Dawn Acoustical survey protocol adopted from Woodbridge and Hargis (2006) can be found in Appendix 1.

Intensive Nest Search Survey

This survey protocol combines the visual searches for signs of goshawk presence (nests, white wash, plucking posts, molted feathers) along closely spaced (20 to 30 m) transects (Reynolds 1982) with Broadcast Acoustical Surveys (see below). Goshawk calls are broadcast along within-stand transects while visual searches are talking place (Woodbridge and Hargis 2006). This protocol is best used when: 1. a goshawk has been detected, but the nesting location is unknown 2. for surveying suitable nesting habitat in the vicinity (100-500 m) of unused nests 3. for surveying for alternative nest locations in suitable nesting habitat within a 1,600 m radius of the last known nesting location.

Broadcast Acoustical Survey

This survey protocol is based on using taped goshawk calls broadcast at specific points along transect routes to elicit responses from defensive territorial adult goshawks and their young. The transect route spacing and call station intervals are designed to maximize both detection probability and survey efficiency within the 600 ha sample units. This is the standard method used by the USDA Forest Service and its efficacy has been evaluated using the response rates at known successful nests (Joy et al. 1994, Kenedy and Stahlecker 1993, Watson et al. 1999) and at territories occupied by non-breeding goshawks (Keane and Woodbridge 2002). Detection rates for Broadcast Acoustical surveys increase with the number of surveys per site, but differ depending on the nesting status of a pair of goshawks. Three surveys per territory plot resulted in cumulative detection probabilities of 0.90, 0.94, and 1.0 for sites with active nests and 0.64, 0.87, and 0.96 for sites with non-nesting pairs (Keane and Woodbridge unpubl. data). Specific details of the Broadcast Acoustical Survey protocol adopted from Woodbridge and Hargis (2006) can be found in Appendix 1.

Nest Check Survey

Once an active nest has been located, subsequent visits will be made to determine the success and productivity of the nesting attempt. Nest checks should occur after the incubation period (June 1st). The nest should be checked from as far away as possible, to reduce the potential for disturbance, but that permits the most unobstructed view into the nest to allow for the visual confirmation of the presence of an adults, nestlings, and later in the season branchlings. Surveyors should attempt to approach and leave nest stands as quietly and inconspicuously as possible.

The above methods will provide the necessary information for the primary indicator, territory occupancy, and will also provide surveys during the time periods required to assess the status of the secondary indicators, nest activity and nest success, for all known or discovered nest locations. Appendix 2 provides a detailed description of how to determine the nest activity and fledgling success from the consideration of field observations.

Survey Schedule

Dawn acoustical surveys should be conducted during the month prior to egg laying, to coincide with the peak of courtship vocalizations by goshawks at their nest sites. Keane (1999) found that goshawks initiated egg-laying from mid to late April (1992,1994) and the first week of May (1993,1995). To best ensure that the month prior to egg laying is included, LTB Dawn Acoustical surveys should be conducted from 15 March through 15 April. Surveys should especially be targeted for 1 April – 15 April, the period that is within 1 month of egg laying, regardless of the egg laying dates reported by Keane (1999). No survey activities should be conducted during the incubation period (15 April – 1 June). Intensive Nest Search Surveys and Broadcast Acoustical surveys should be conducted during the nestling and fledgling stages, corresponding to 2 June-15 August. Surveys from 2 June thru 12 July cover the nesting period, when young have recently hatched and are reliant on adults for food and thermoregulation. Surveys conducted from 13 July thru 15 August cover the fledgling period where young are old enough to begin to leave the nest. No surveys should be conducted after August 15, due to the issues of dispersal and migration confounding survey detections. **The LTB goshawk monitoring coordinator will need to compare these recommended dates with nesting chronology data that will be collected during the monitoring program to ensure that they are accurate.**

Statistical Considerations

Background

It is essential to determine, a priori, the probability of detecting significant declines and to choose an adequate sample size to be able to detect those changes with an acceptably high probability. The null hypothesis, that there has been no change in the population index over a 10-year period must be tested against the alternative that the population has changed (either increased or decreased: two-tailed test) or declined (one-tailed test). Because the monitoring program is focused on protecting goshawks throughout their contemporary distribution in the LTB, we are only concerned with detecting a decline (one-tailed test).

The power of a statistical test depends on three parameters: the significance criterion (α), the reliability of the sample results (variation), and the 'effect size', the degree to which the phenomena exists (Cohen 1988). We must therefore ask the question: 'if a significant decline in the population index has occurred, what is the probability that we can detect it?' Clearly the answer to this question is critical to the monitoring program. The probability of detecting a change, if it has in fact occurred, is called statistical power ($1-\beta$); where β is the probability that a statistical test will generate a false-negative error or Type II error. Given a sampling design and a desired level of change to detect in our population index, we conduct an 'a priori' power analysis to determine the sample sizes necessary to detect the desired level of change at several probability levels. In doing so, we seek to optimize the balance in statistical certainty with the logistical constraints of funding and conducting this monitoring program.

Statistical power is strongly influenced by the significance level or Type I error rate, α (Field et al. 2005). In the context of a monitoring program, α is the probability of declaring a population has declined when, in fact it has not. A Type II error rate, β is the probability of failing to detect a decline that has actually occurred. A Type II error is more detrimental in the context of conservation, because it results in missing a decline when it has actually occurred. While α is commonly set at 0.05 in many other statistical tests, in a monitoring context, both α, β, and the costs for conducting monitoring should be carefully considered collectively (Field et al. 2005). Furthermore, the maximum sample size is constrained due to the number of actual goshawk territories that can be supported in the LTB, estimated from 24 (Keane 1999) to 32 (LTB goshawk database). To accommodate this small range sample sizes of goshawk territories, we could only consider conducting simulations (see below) with only α probability level equal to 0.20 and β probability equal to 0.20. Simulations with an $\alpha < 0.2$ will all result in β probability < 0.20.

Statistical Power Simulations

We calculated statistical power using two programs written by J. Baldwin (PSW Statistician), one with custom power calculations in excel and one using SAS (v8, SAS Institute 1999). We used parameter estimates for initial occupancy from estimates provided by Keane (1999, 4-year mean occupancy rate = 88.5 [SE = 7.9]) and from our review of the goshawk database for the LTB. Visit-specific detection probability estimates for Broadcast Acoustical Surveys and Dawn Acoustical Surveys were taken from Woodbridge and Hargis (2006, page 3-8 and Table 3.2). We determined relevant range of sample unit sample sizes by considering the total estimated number of territories that the LTB could support at any one time (n = 24) and the total number of territories currently known from the LTBMU goshawk database (n = 32).

We simulated a decline, from 20-30%, in the population index (territory occupancy) over a 10-year period. We selected a one-tailed test because we are only interested in determining whether the index has declined from one sampling period to the next. Selecting a one-sided test has more power than a two-tailed test at the same α level, and thus requires a smaller number of sample units (approximately 50% fewer) and a smaller budget. Once we determined the optimal sample size for the 10-year period, we then conducted a second power analysis to determine what levels of change could be detected with statistical confidence. This second power analysis will reveal what levels of short-term (e.g., 2 or 4 years) changes can be detected by the design.

For the 10-year trend power analysis, we first had to determine the optimal sampling frequency within the 10-year period. To determine this, we conducted prospective power analyses varying the number of years in which surveys are conducted while holding all other values constant (Table 3). The number of survey years had a small effect on power. However, the most optimal design, considering cost per year of sampling and statistical power, is for 3 surveys conducted at 4-5 year intervals and this design will be used for the next phase of the power analysis.

Table 3. The effect of the number of surveys and the survey interval on power. α, ψ, and the number of sample units were set at arbitrary levels and held constant.

α	Power 1-tail	Initial Occupancy (ψ)	Sample Units	# Surveys (interval)	Years Sampled
0.2	0.728	0.85	30	2 (9)	1,10
0.2	0.728	0.85	30	3 (4.5)	1,5,10
0.2	0.752	0.85	30	4 (3)	1,4,7,10
0.2	0.733	0.85	30	5 (2)	1,3,5,7,9
0.2	0.845	0.85	30	6 (2)	1,3,5,7,9,11
0.2	0.887	0.85	30	10 (1)	1-10

A prospective power analysis is only useful when realistic values are used for the parameters required to conduct it. In an occupancy modeling power analysis, the initial proportion of sample units occupied (ψ) has a strong influence on the sample size that will be required to detect a decline in the index. To determine a likely range of initial proportions of sample units occupied by goshawks, we conservatively used values near the mean and lower 95% confidence interval (.75, 0.80, 0.85) for territory occupancy rates reported by Keane (1999) for the LTB. We also conservatively selected the lower survey-specific detection probabilities (survey 1 = 0.64, survey 2 = 0.87, survey 3 = 0.96) for the Broadcast Acoustical Surveys conducted in non-reproductively active goshawk territories.

Once a territory is established, it is likely to remain occupied by at least one member of the same pair of goshawks for >2 years. Detrich and Woodbridge (1994) found that 70-75% of territories were occupied by the same goshawks in successive years. Males averaged 1.3 (SE = 0.09) years and females 1.8 (SE = 0.21) years of consecutive occupancy of the same territories. Furthermore, goshawks in the LTB are non-migratory, likely increasing the rates of territory persistence by the same pairs than in areas where populations are migratory. Territory persistence will have the effect of increasing the statistical power to detect changes. However, the amount is unknown and will have to be estimated with new data. We have not attempted to use a territory persistence factor in these power analyses, thus our estimates for power displayed here will be biased low, but likely by a small amount. Thus, our estimates of power are conservative and are likely to be slightly higher than presented here.

Our analysis estimates that the monitoring program will need a sample size of 20-30 sample units to have the highest likelihood of detecting a ≥25% decline, given an initial occupancy of ≥0.85 and ≥0.80, respectively (Table 4a). A key limiting factor for this analysis is the actual number of territories actually occupied during a year in the LTB. Our best estimate is that 19-23 territories are typically occupied, limiting the number of sample units that can be included in the monitoring program to 20-30 when $\psi > 0.8$.

While we have developed the monitoring program to detect a trend over a 10-year period, declines may occur more rapidly. To address this potential we conducted a second power analysis to determine what level of change could be detected between any two sampling periods (2 year interval) given there will be 20-30 sample units included in the monitoring program (Table 4b). With a sample size of 25, a decline of ≥25% can be detected between any two time periods during the 10-year sampling period. Thus, the program is capable of detecting both slow and rapid rates of decline.

Evaluating Stressor Related Effects

The purpose of the design and statistical considerations to this point have been to develop a rigorous approach to detect a significant decline in a population index, territory occupancy. While the proposed approach is capable of doing so, it will not necessarily identify the cause(s) for the decline. Because multiple stressors, not a single stressor are acting on the goshawk population in the LTB, an approach is needed to evaluate the effects that the key stressors may be having. To achieve this, stressors must be measured and compared with goshawk territory occupancy and reproduction patterns to determine whether and how they are affecting the occupancy and reproduction. Occupancy modeling allows for the investigation of factors that affect the detectability of a species and for factors that affect the occupancy of a species at a particular location (site specific covariates). Stressors will be treated as site specific covariates and used to explain the patterns of goshawk occupancy. Similarly, habitat characteristics known or hypothesized

Table 4. Prospective power analysis results for (A) detecting a 20-30% decline in the goshawk population index for an entire 10-year period (sampled every 4-5 years) when there are 3 survey periods and (B) the level of change capable of being detected between any two 2 time periods during the 10-year period, under the varying parameter conditions listed.

A. Trend Over 10-years (3 sampling occasions)

α	Power to Detect -20%	-25%	-30%	Initial Occupancy (ψ)	Sample Units Required	# Territories Occupied
0.20	0.54	0.63	0.71	0.75	20	15
0.20	0.58	0.67	0.76	0.80	20	16
0.20	0.63	0.73	0.81	0.85	20	17
0.20	0.70	0.80	0.87	0.90	20	18
0.20	0.58	0.67	0.76	0.75	25	19
0.20	0.63	0.72	0.81	0.80	25	20
0.20	0.68	0.78	0.86	0.85	25	21
0.20	0.75	0.85	0.91	0.90	25	23
0.20	0.62	0.72	0.81	0.75	30	23
0.20	0.67	0.77	0.85	0.80	30	24
0.20	0.73	0.83	0.90	0.85	30	26
0.20	0.65	0.76	0.84	0.75	35	26
0.20	0.71	0.81	0.88	0.80	35	28
0.20	0.77	0.86	0.93	0.85	35	30

B. Detectable Level of Change Per Sampling Interval (4-5 Years)

α	Power	Initial Occupancy (ψ)	Sample Units	Detectable Decline
0.20	≥0.80	0.75	25	30%
0.20	≥0.80	0.80	25	27%
0.20	≥0.80	0.85	25	24%
0.20	≥0.80	0.90	25	20%

to be important to goshawks (e.g., see Young and Morrison 2007) will also be included as site specific covariates. Inclusion of habitat and stressor variable into the analysis will allow for the comparison of the relative importances of these elements to goshawk territory occupancy and reproduction. Models consisting of single stressors and habitat covariates as well as combinations of >1 stressor/habitat covariate will be compared to a model without stressor/habitat affects (null model). It is important to understand that this analysis will only produce goshawk-stressor associations, and while they can suggest cause and effect relationships, focused research efforts will be necessary to confirm these relationships. However, the detection of goshawk-stressor associations, if present, is an important step toward developing management strategies to protect the goshawk population in the LTB.

We previously identified the five primary stressors and linked them to their hypothesized effects on goshawks (Figure 4). We have selected the hypothesized effects that match the population indexes we have chosen for our monitoring design in Table 5. As previously mentioned, these hypotheses were based on previous knowledge and existing literature. These hypotheses can be translated into competing models to describe patterns of territory occupancy and reproduction.

Table 5. Hypothesis about stressor effects on goshawk territory occupancy and reproduction patterns in the Lake Tahoe Basin.

Stressors	Hypothesized Effects
Urbanization, Ski Resorts, Vegetation Management, Motorized & Non-motorized Recreation	1. Reduced Distribution: Negatively effects territory occupancy, resulting in absence beyond a certain spatial threshold. 2. Reduced Nest Activity and Nest Productivity: Negatively effects ability of the goshawk pair to initiate nesting or to produce a successful nest. 3. Reduced detection probability due to lower use of habitat near sites with stressor effects.

The measurement of stressors must take into account the temporal and spatial extent of the stressor as well as its intensity. In addition, each stressor must be measured in a manner appropriate to match the resolution of the marten data being collected. To achieve this match we propose that stressors be measured with regard to their spatial extent of influence at two spatial scales: (1) at the scale of the sample unit (2) at the scale of their breeding territory. We have already defined the sample unit, but because we do not known the actual extent of any goshawk pair's breeding territory, nest locations will be buffered with a circular area equivalent to the mean breeding territory for a male goshawk (2698 ha). Thus for each stressor, a GIS coverage will need to be used or created to identify the spatial locations of each stressor. For each stressor, we identify important elements of temporal extent and intensity to include in their measurement (Table 6). For example, vegetation management has been conducted in several forms (e.g., selective logging, fuels treatments, prescribed fire) occurring over several decades and should be measured to represent the differences in methods and time since treatment.

Stressor and habitat-related variables will be generated for all sample units. These stressor variables will be used to evaluate their influence in describing the sample unit and territory specific patterns of occupancy and reproduction in the LTB following the analysis protocol described in section VII. This analysis should first be conducted retrospectively using the existing goshawk database to be able to compare goshawk territory occupancy and reproduction with existing stressors (e.g., ski resorts, urbanization). Because we have selected territories to monitor that largely have been occupied within the last thirty years, we are only able to detect how existing and new stressors affect these contemporary territories may affect decline if they occur. Stressors that have been present for some time may have already had their effect (e.g., reduced the distribution of goshawk territories) that will not be detectable by the territories selected for the monitoring program.

Table 6. Stressor data layers to be used or created and be used as the basis for measuring stressor influence for each sample unit.

Stressor	Data Source
Urbanization	Parks et al. (in review) Urbanization Index for the LTB
Ski Resort	Create a coverage with the footprints of all ski resorts in the LTB
Vegetation Management	Fuels Treatments- at this stage a single coverage to identify the areas treated, when they were treated, and how they were treated (e.g., treatment prescription)
	Past Logging- assemble a coverage identifying the spatial extent, date when it occurred, and the type (e.g., selective, clearcut) of past logging in the LTB. Consider using the FACTS database for this purpose.
Motorized Recreation	Use existing coverages to create a single coverage including all the major routes of travel for high-speed (e.g., >35mph) vehicles. Assign each route a relative traffic volume category (e.g., high, medium, low volume).
Non-motorized Recreation	Trails and proximity to urban areas can be used as surrogates for non-motorized recreation use.

The stressor analysis for the monitoring program will only be capable of detecting the effects that stressors have on territory occupancy or reproduction for the subsample of locations selected. The analysis of stressor effects should occur every 4-5 years to provide feedback on how the goshawk population is responding to stressors. Finally, additional stressors can be added to this analytical framework if new information warrants their inclusion.

Cost Estimates for Field Data Collection

Ferland et al. (2006) field tested the North goshawk bioregional monitoring design and estimated that to conduct 2-Broadcast Acoustical surveys in 20 688 ha sample units resulted in a cost of about $1060 per sample unit in 2003. These cost estimates included hourly wages (11.05/hr), commute time, vehicle costs, equipment, and training time.

Using the estimates of Ferland et al. (2006) we estimate that each sample unit will cost ~$1500 to sample using either of the 3-survey protocols described herein. Thus, for the recommended sample size of 20-25 sample units, we estimate an annual budget of $37,100 to $46,375 per sampling period (Table 5).

Table 5. Estimated costs for field data collection for a single sampling period. All estimates are for FY 2007 costs and do not include annual wage increases. A 75% increase was added to each estimate to include an additional survey for each sample unit, increase in hourly wages from 2003 GS-5 costs, and unforeseen additional costs. The gray highlighted row indicates the costs for the selected design.

		Sampling Strategy	
Number of Sample Units	Total Cost for Field Labor (Ferland et al. 2006 est.)	1-Year Complete	10 –Year Program*
20	(20 * $1060)*1.75 =	$37,100	$111,300
25	(25 * $1060)*1.75 =	$46,375	$139,125
30	(30 * $1060)*1.75 =	$55,650	$166,950
35	(35 * $1060)*1.75 =	$64,925	$194,775

*This is for 3 sampling occasions, once every 4-5 years, for 10 years.

If the primary indicator is the only indicator of interest, the 3rd visit can be dropped for sites with detections in the first 2 visits. This will result in a ~20% decrease in the survey effort and budget required. Furthermore, additional savings will occur for each territory with a known active nest location as the revisits to the nest require a minimal amount of field time in most cases.

Equipment, Data Management, and Analysis Costs

The additional costs for the program include the initial equipment required to conduct the work (see Appendix 2) and the support staff time required to supervise field crews, enter and proof data, conduct analysis and write up the results. The amount of specialized field equipment needed is minimal. Only, calling devices, consisting of CD or mp3 players and a small megaphone, are required for Broadcast Acoustical Surveys. Together these calling units should cost of ~ $75 per unit. It is likely that only 4-6 calling units will be required, equaling ~$300-450 for equipment costs. We generally estimate that it will take 1 months of time to enter and proof database. Costs for the previously mentioned duties will depend on whether staff time for existing employees will be dedicated for this project or not. We strongly recommend that the individuals likely to conduct the first year(s) of analysis consult with the principal investigators to ensure proper treatment of the data, proper execution of the analysis, and to be able to incorporate any advances in the types of analysis available for the data.

Sample Unit Selection

We selected the 25 territories that met the following criteria: 1. the most recent and consistent confirmed nesting or detection records 2. representative of the geographic locations of goshawk territories in the LTB 3. representative of the 'anthropogenic stressor gradient' (low to high) found in the LTB (Appendix 3). Criterion 1 was necessary due to the constraints of the sample size/initial occupancy requirements for the designs capable of detecting >20% decline with 80% power over a 10-year period. The latter 2 cirteria were included to ensure the selected territories were representative, with regard to their location in the LTB and their exposure to anthropogenic stressors, of the overall population of territories distributed in the LTB.

VIII. Data Collection and Analysis Protocol

Field Protocol

Locating Survey Stands and Transects

Detailed maps including all the pertinent survey (e.g., nest locations) and location information (e.g., roads, navigation features) should be created prior to leaving for field sites. Maps should include sample unit boundaries, survey stations, and if appropriate survey transects. Field personnel should study the sample units, their access, and nest/detection locations, and previous survey history prior to leaving for the field. GPS coordinates and if appropriate transect routes should be entered into GPS units in the office to maintain accuracy and efficiency. All survey routes and transect should be archived in GIS coverages for future use.

Data Management and Analysis Protocol

The database manager is the goshawk monitoring coordinator for the LTBMU and the data will be housed wherever the coordinator is located.

Occupancy Estimation

There are two steps for the data analysis: (1) estimate territory occupancy and (2) estimate the status or trend between years. The first step involves creating detection histories for each sample unit by indicating with a 1 (detection) or 0 (non-detection) whether a goshawk was detected on each survey (e.g., 101, where goshawks were detected on the 1^{st} and 3^{rd} surveys but not the 2^{nd}). The detection histories are then used to estimate ψ, the proportion of territories occupied based on the number of sample units surveyed with goshawk presence in each of the two survey strata: (1) known nest location (2) unknown nest location. ψ can be estimated in program PRESCENCE (MacKenzie and Hinze 2006) using the detection histories from the surveys.

The first step in estimating occupancy is to fit a model to the detection history data. Due to the fact that two different survey protocols are used, we suspect that the survey-specific detection probabilities may differ between these two. To specifically account for this difference, a survey covariate is added to differentiate between the two survey protocols. The survey covariate simply needs to differentiate the two survey types using a binary set of values (e.g., known or unknown). Furthermore, the detection history dataset should be explored with the candidate set of models incorporates both standard models included in program PRESENCE (version 2.0, MacKenzie and Hinze 2006) and custom models representing hypotheses on how additional covariates may influence detection probability. Standard models included covariates that assume p is constant across visits (constant p), that estimate p individually for each visit (visit-specific p), and assume that heterogeneity exists in the data such that the data are better modeled if partitioned into two groups (2-groups).

The relative performance of all models to describe the detection history data are evaluated by comparing their Akaike Information Criterion for small sample size (AIC_c) values and AIC_c weights (*w*) (Burnham and Anderson 2002). The top model(s) are used to estimate the probability of detection (p) and occupancy (ψ). Estimates of occupancy (ψ) and their associated coefficients of variation (e.g., SE's) will be used for the status and trend analysis described next.

Status & Trend Analysis

For the analysis of any 2 years of occupancy data (status), the analysis for a difference between any 2 time periods is done using McNemar's t-test (one-tailed or two-tailed) which is a test for differences between paired proportions (O'brien 1998). For multiple years (trend), the analysis is a logistic regression.

Analysis of Stressor Effects

Stressors will be measured in GIS at two spatial scales, sample unit and territory, for each sample unit. For the monitoring program, the effects of stressors on territory occupancy can be investigated by including them as site-specific covariates to explain territory occupancy in program PRESENCE (version 2.0, McKenzie and Hinze 2006). Stressor effects on reproduction will have to be evaluated using each nesting location as the unit of measure and it's reproductive performance over a number of years. Goshawk nesting activity and nesting success are strongly influenced by annual variation in intrinsic factors (e.g., spring weather, prey population cycles). However, these effects likely influence the majority of goshawks in the LTB simultaneously. Knowing this provides the opportunity to account for these annual fluctuations and investigate whether extrinsic stressors have additional further impact to goshawk reproduction in the LTB. Due to the high rate of annual variation in goshawk reproduction and small sample size of nests, ~5 years of data will likely be required before stressor effects can be adequately tested. However, analysis of the existing reproduction information from 1977-2007 may improve the understanding of the sample sizes required.

A substantial amount of data currently exists to conduct preliminary investigations of stressor effects. However, most survey efforts were not rigorous enough to provide reliable occupancy estimates, making using the results of previous survey information challenging. The existing data will have to be carefully filtered to include only those territories with adequate survey effort in any analysis, or alternatively use an analytical approach that uses presence data only. LTBMU staff should consider conducting analysis using existing data as a retrospective approach to testing stressor hypotheses. If a logistic regression approach is used, a competing set of models including some with stressor variables can be used to determine what factors best explain the variation in goshawk territory occupancy and reproduction.

Quality Assurance and Quality Control

Ensuring Accurate Field Data Collection

Supervisors of field crews should make unannounced visits to sample units with field personnel to evaluate the accuracy of execution of the sampling and data collection protocol. Field supervisors should conduct routine screening of all data forms to ensure completeness and accuracy. Field supervisors are responsible for correcting errors in execution of a field related protocols.

Evaluation of Data Accuracy

We have previously provided mechanisms for supervisor review of field data, verification of tracks, and proofing of data of field forms, and in the final database.

Evaluation of Analysis Accuracy

Both interim and final analysis should either be completed in collaboration with the principal monitoring program authors or with others experienced in the analysis and interpretation of the carnivore monitoring data. One or more independent reviews from researchers well qualified to evaluate this type of analysis, the results, and their interpretations is also suggested.

Equipment and Training

Coordinator Experience

The goshawk monitoring coordinator should have experience with the survey methods, survey equipment, database management, and with training and managing crews to collect field data. The coordinator needs to be familiar with the goshawk territories, nesting habitat characteristics, and the goshawk database for the LTB.

Field Data Collection

A detailed list of the required equipment is listed in Appendix 4. Individuals involved in field data collection should be well trained in navigation with both GPS and map-compass-altimeter together top have the ability to accurately locate stations. Field personnel should be trained in data collection procedures involved. All field personnel should be trained in first aid and in communication protocols (e.g. use of radios). Prior experience in any or all of the above is preferential.

The goshawk monitoring coordinator will conduct training for all surveyors on the visual identification of goshawks versus all potentially confusing species, use the 2 training products, *Voices of Western Forest Raptors and Sound-Alikes* and *Feathers of Western Forest Raptors and Look-Alikes* (found in Woodbridge and Hargis 2006), for training on the identification of goshawks by sound and sign. Training will also include field visits to known goshawk sites where trainees can observe breeding goshawks.

Survey crews will include a minimum of 2 people, one of which will be assigned as the crew leader. The crew leaders should be the individuals with more field experience with goshawks and their survey methodology such that they can help train the less experienced member of the survey team. Each crew leader is responsible for checking the field data forms for completeness and accuracy prior to submitting them to the goshawk monitoring coordinator.

IX. Flexibility in altering the monitoring program

The monitoring program has the capacity to be flexible to some changes. The most significant consideration of alteration of the program should take place after the first two years of surveys. After the first year, actual estimates of initial occupancy will be in hand to determine the most optimal number of sample units to include. After the second year, estimates of persistence within territories will be generated and these can be applied to adjust power analysis estimates and confirm the optimal sample size for the monitoring program. **Any changes to the program should only be done in consultation with the authors or others well experienced with the monitoring and analytical methods used in this program. Changes to the monitoring program, done without careful consideration of their effects, can result in the failure of the program's capability to detect the specified amount of change over the specified time period.** Additional stressors can be added to the analysis if warranted.

Acknowledgements

We would like to thank D. Hansen and B. Woodbridge for review of the monitoring plan.

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Figure 1. Distribution of Northern Goshawk nest and detection records for the Lake Tahoe Basin for two periods from 1977-2007. Nest records exists from 1977-2007 and detection records exist from 1992-2007. Records from >2000 are more complete due to improved survey methods.

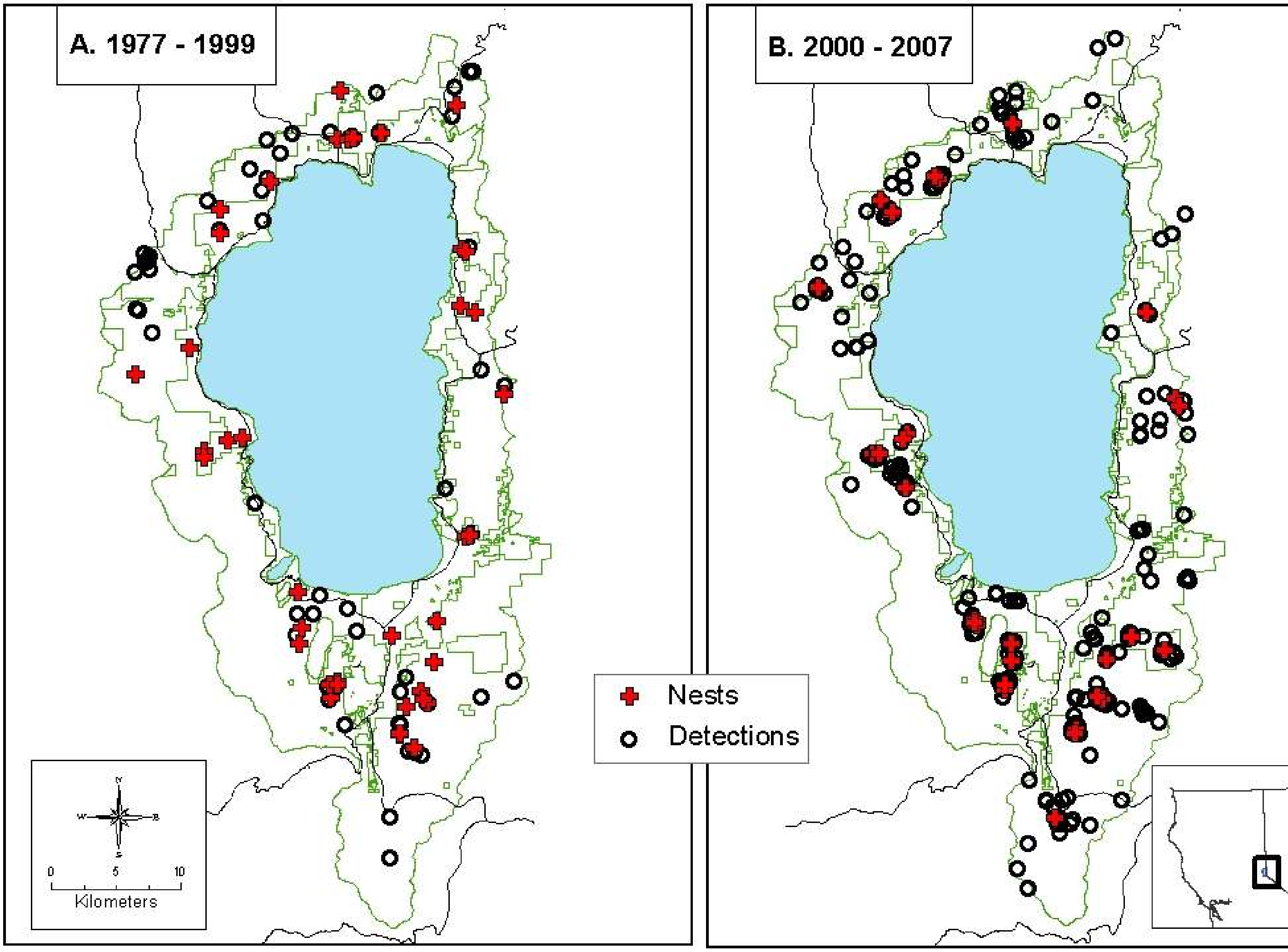


Figure 2. Conceptual diagram of a prospective environmental monitoring program. Indicators are selected in the context of known or hypothesized stressors to goshawks (adopted from Noon 2003).

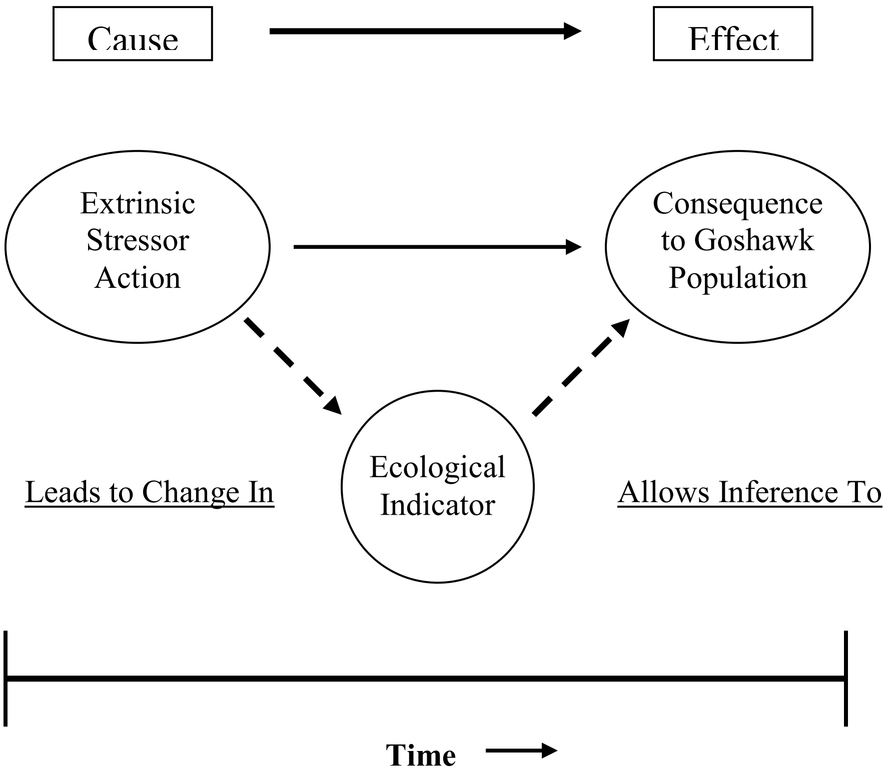


Figure 3. Conceptual model of the relationships between the point of initiation of a monitoring program and retrospective and prospective detection of change. Dashed lines indicate how knowledge gained from retrospective analysis will be incorporated into prospective detection of change.

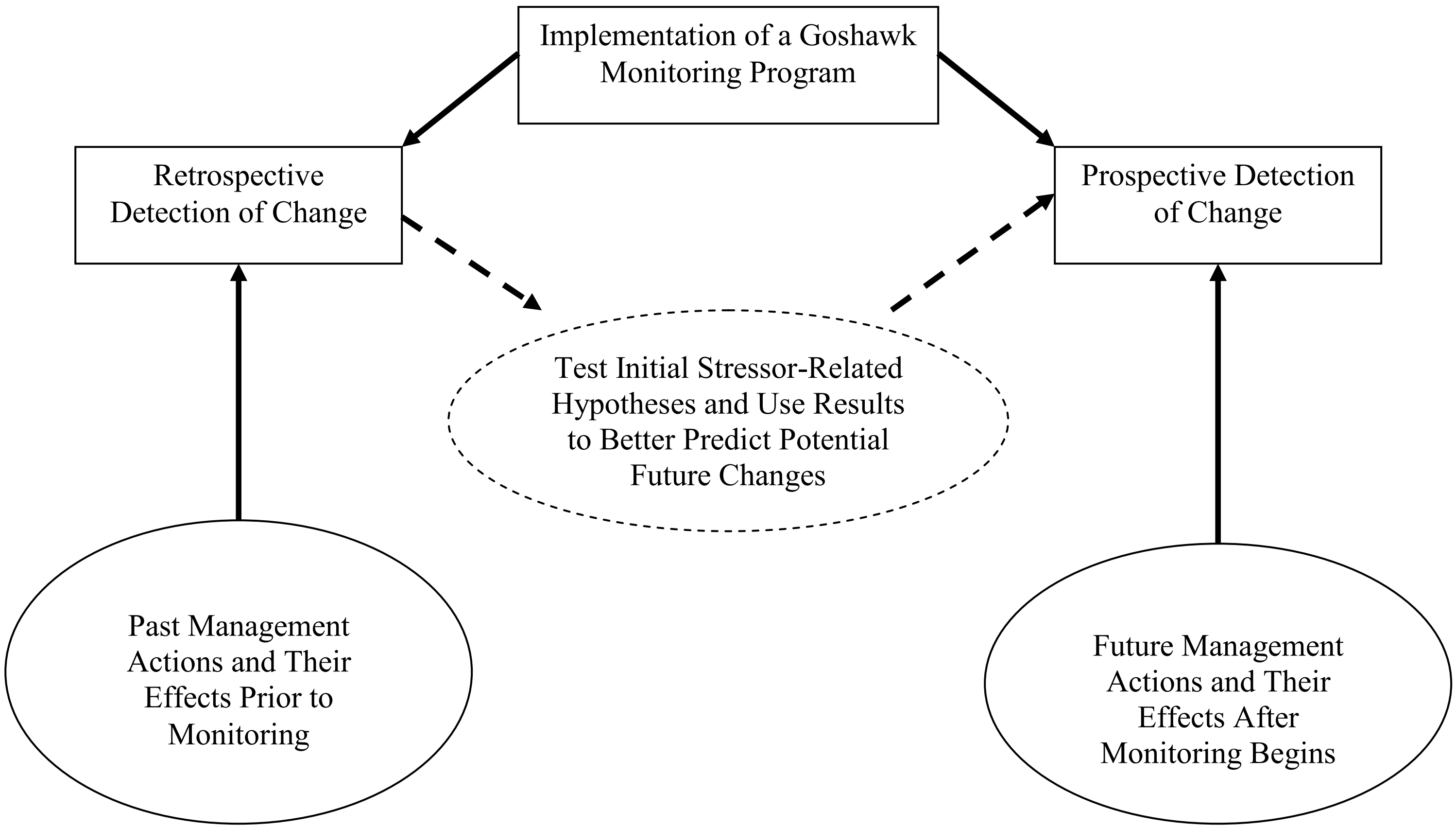


Figure 4. Conceptual model linking the primary stressors for Northern goshawks in the Lake Tahoe Basin to their ecological consequences, and how these consequences are related to population responses.

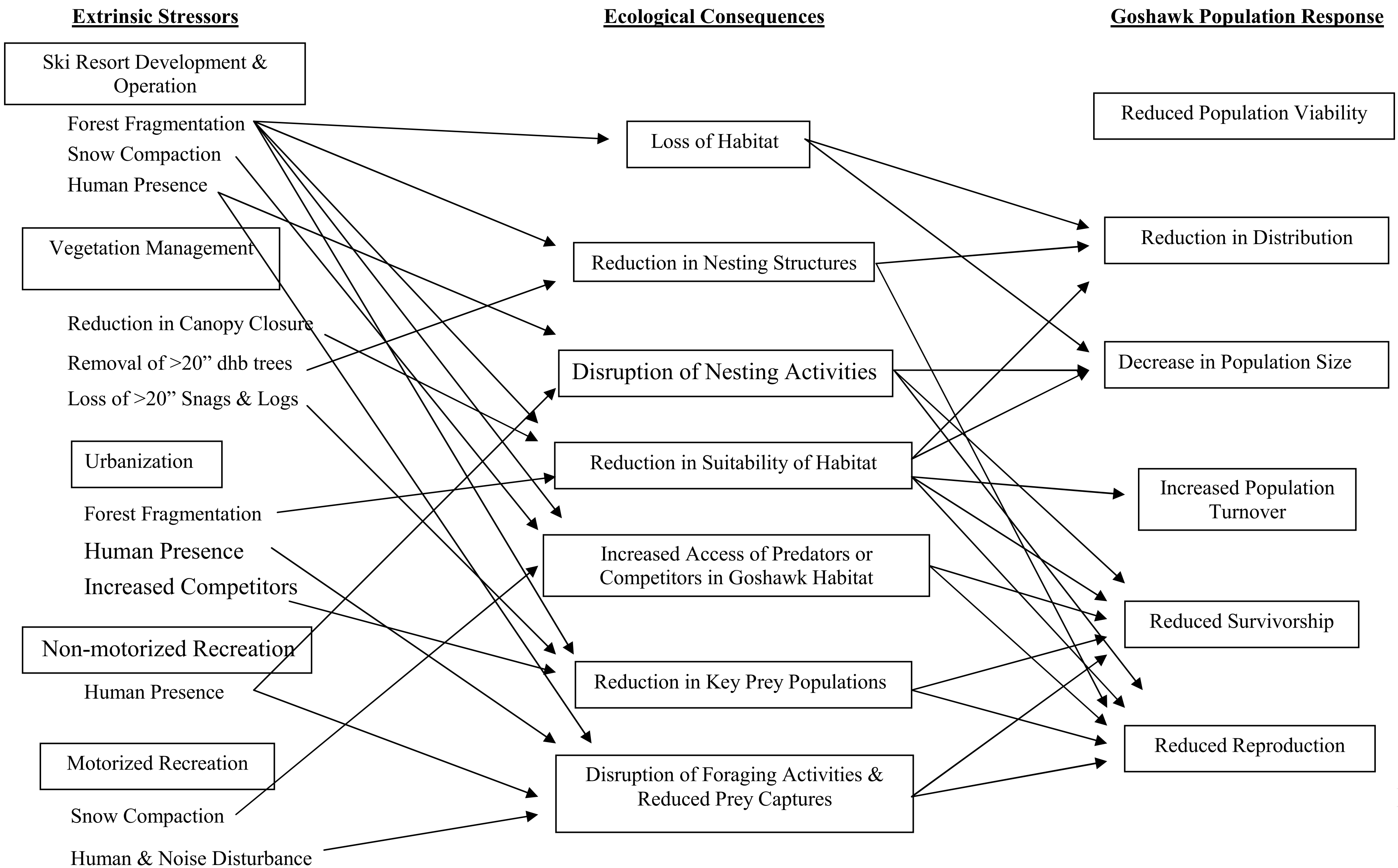


Figure 5. The 45 selected FIA territory hexes in the Lake Tahoe Basin.

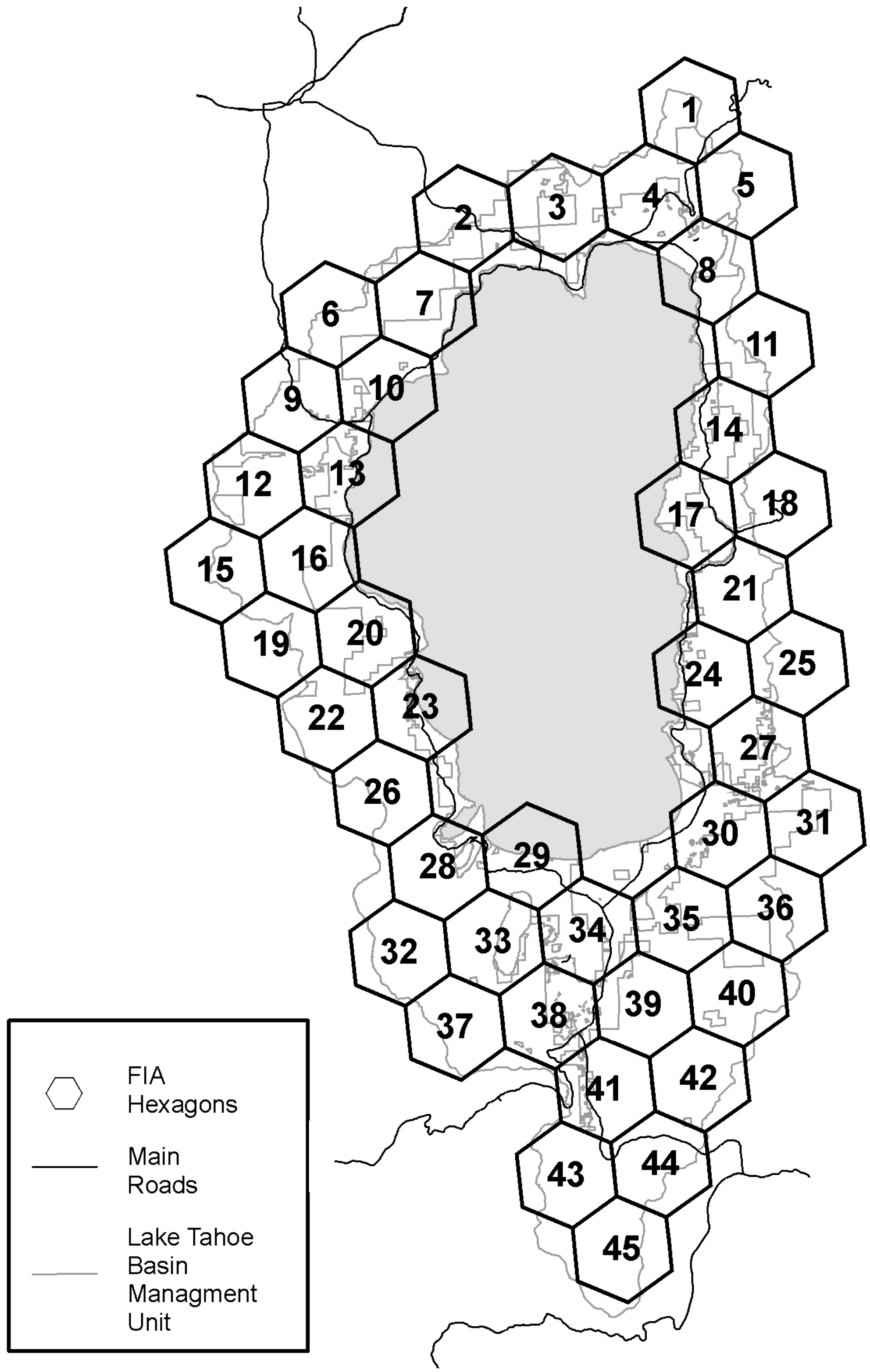


Figure 6. Forest Inventory and Analysis hexagonal grid cell with the four nested 600 ha sample units within each. This sampling grid is nested within the Sierra Nevada Bioregion goshawk survey grid. Thus, the sample unit locations are fixed and cannot be modified.

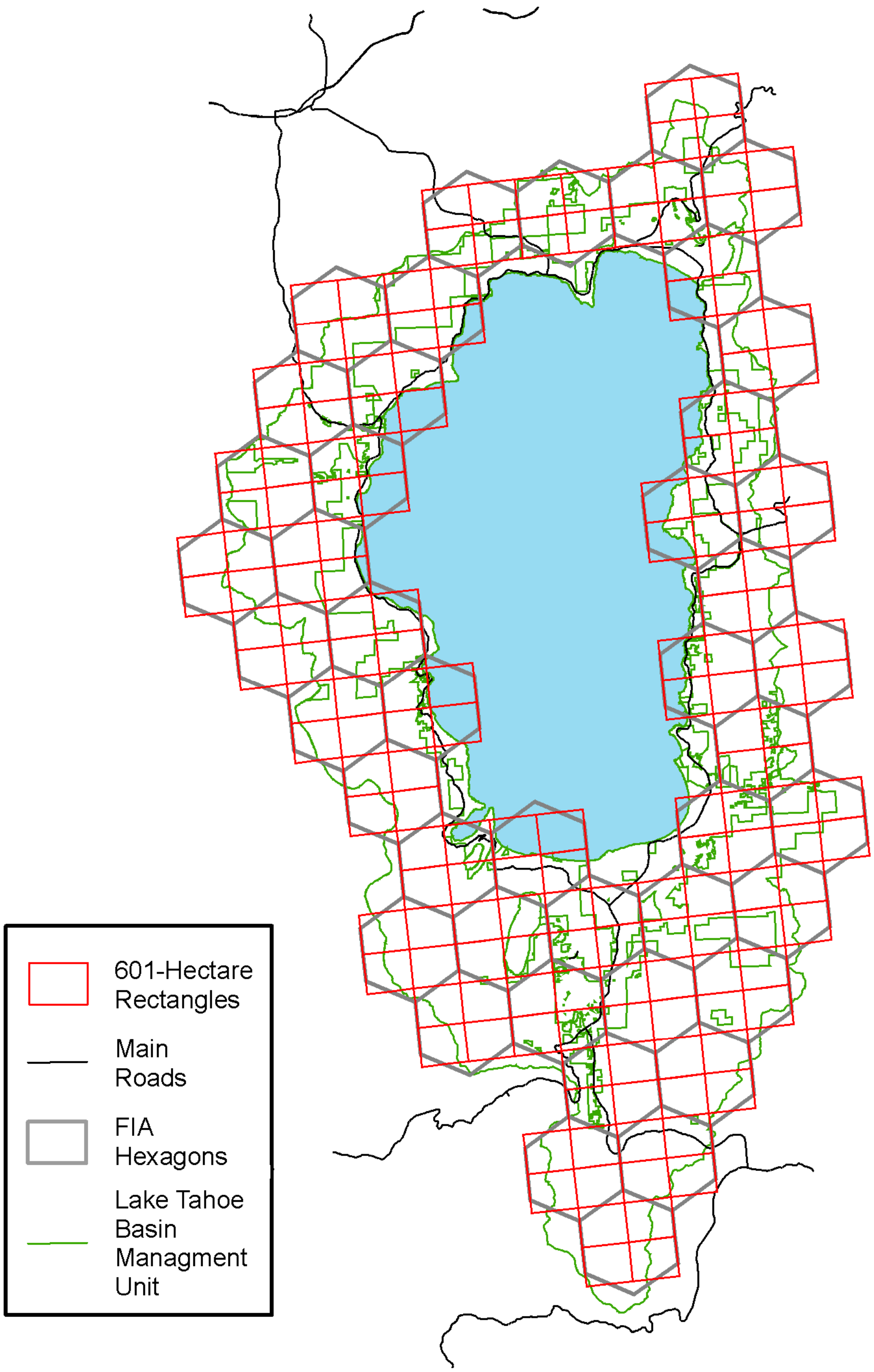


Figure 7. Sample units and Northern goshawk nest locations from surveys conducted from 1977-2007.

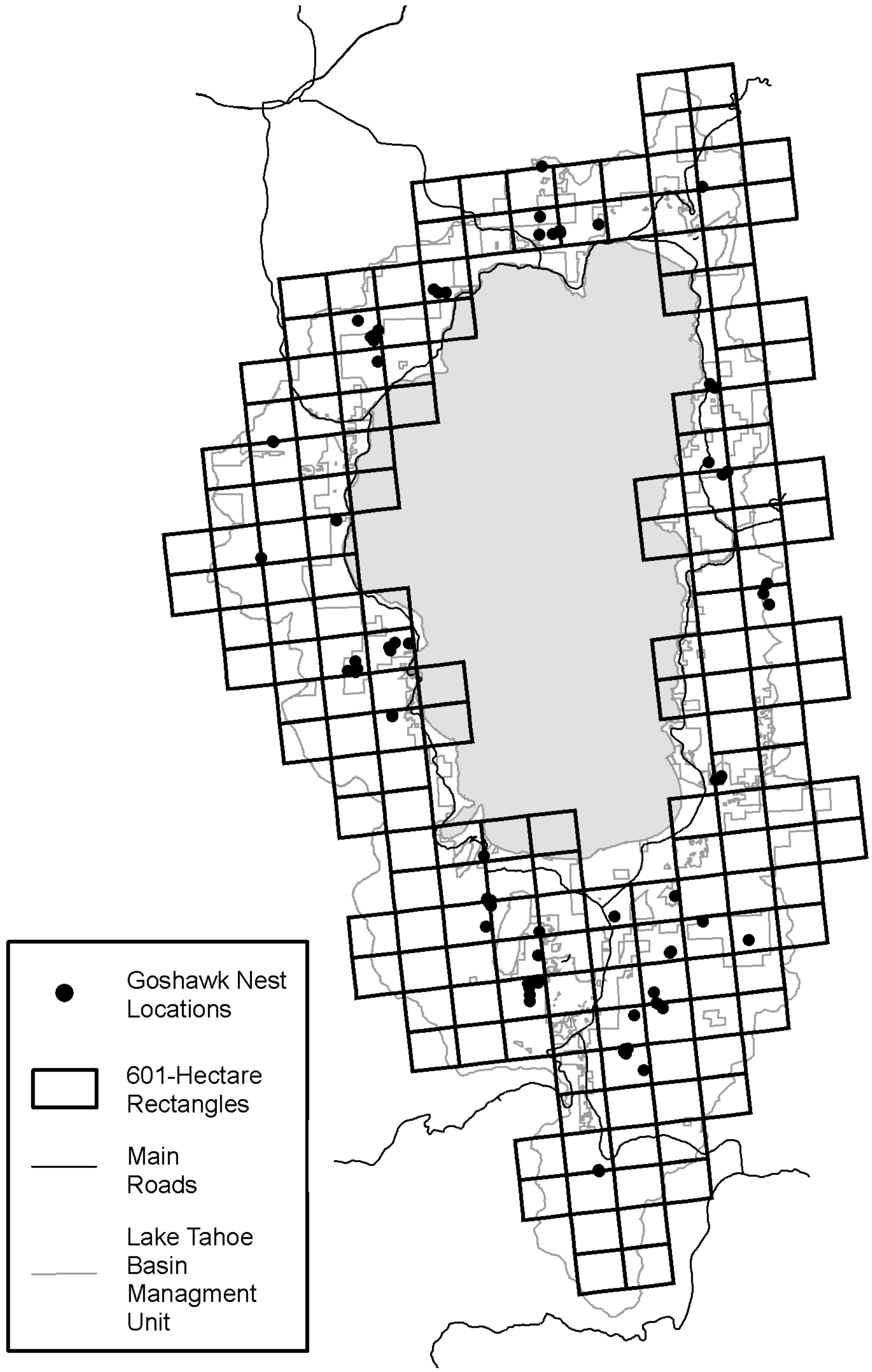


Figure 8. Sample units and Northern goshawk detections from surveys conducted from 1977-2007.

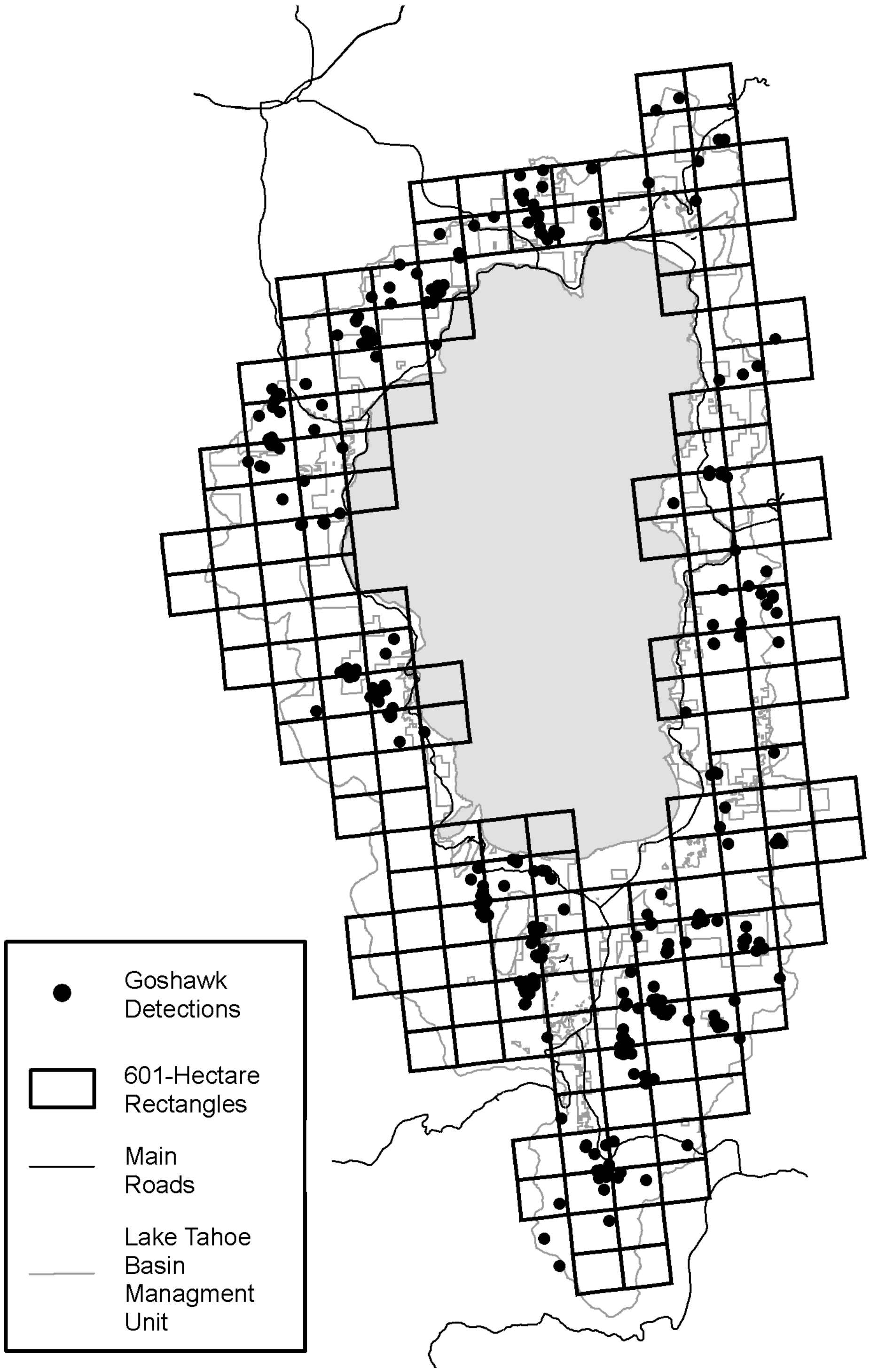


Figure 9. Sample unit survey priority ranking.

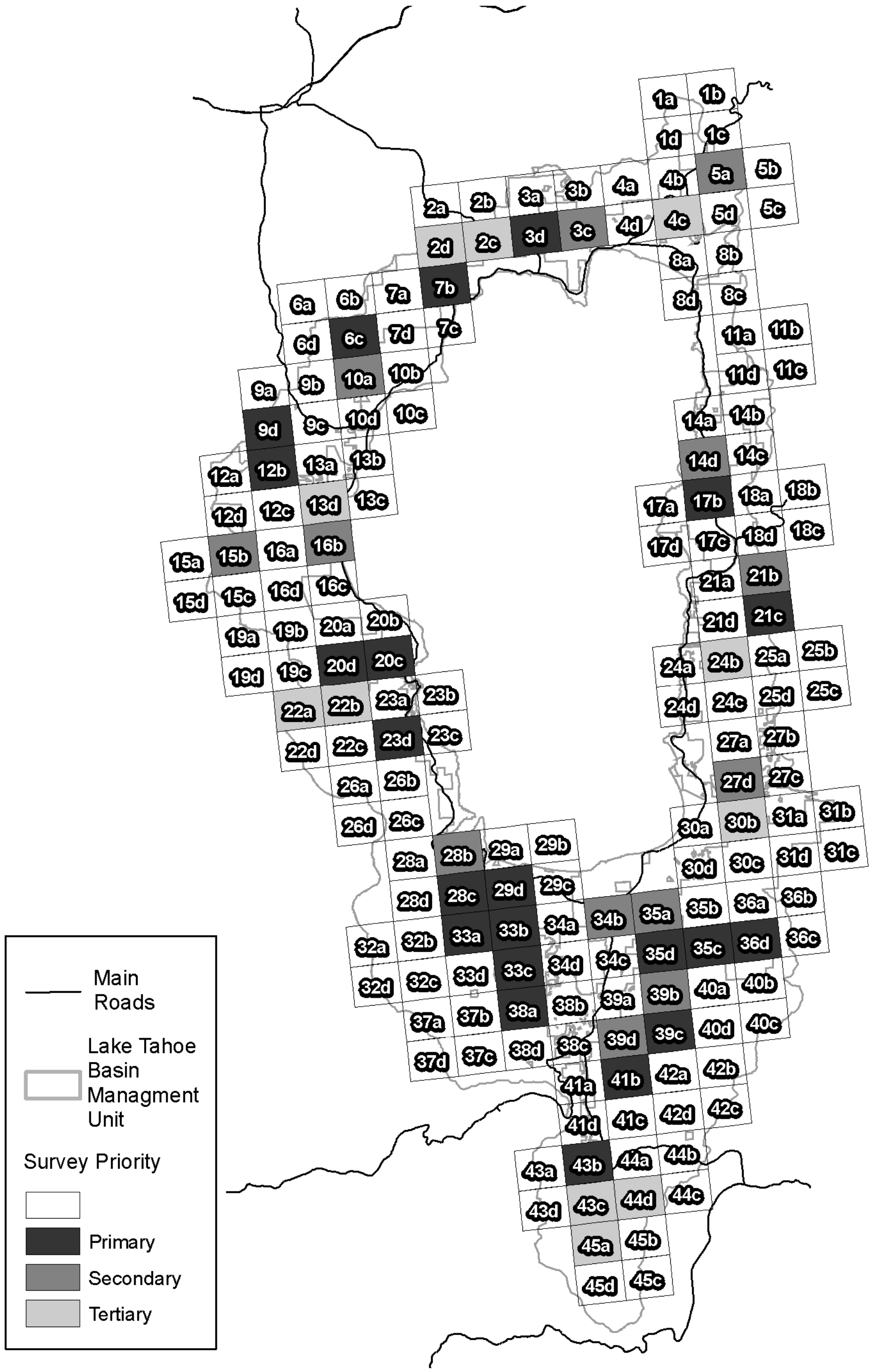


Figure 10. Decision tree for field protocol sampling procedures.

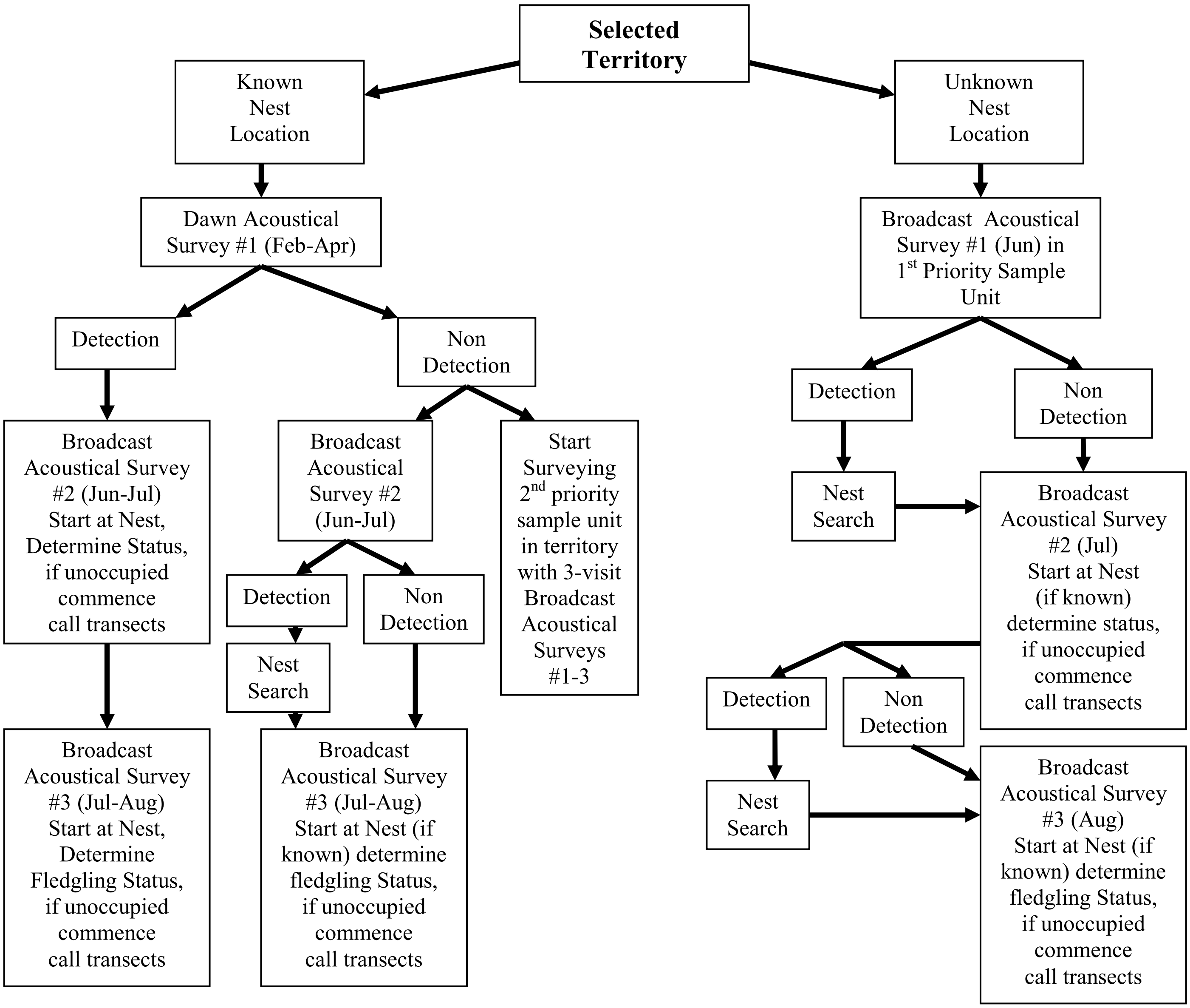
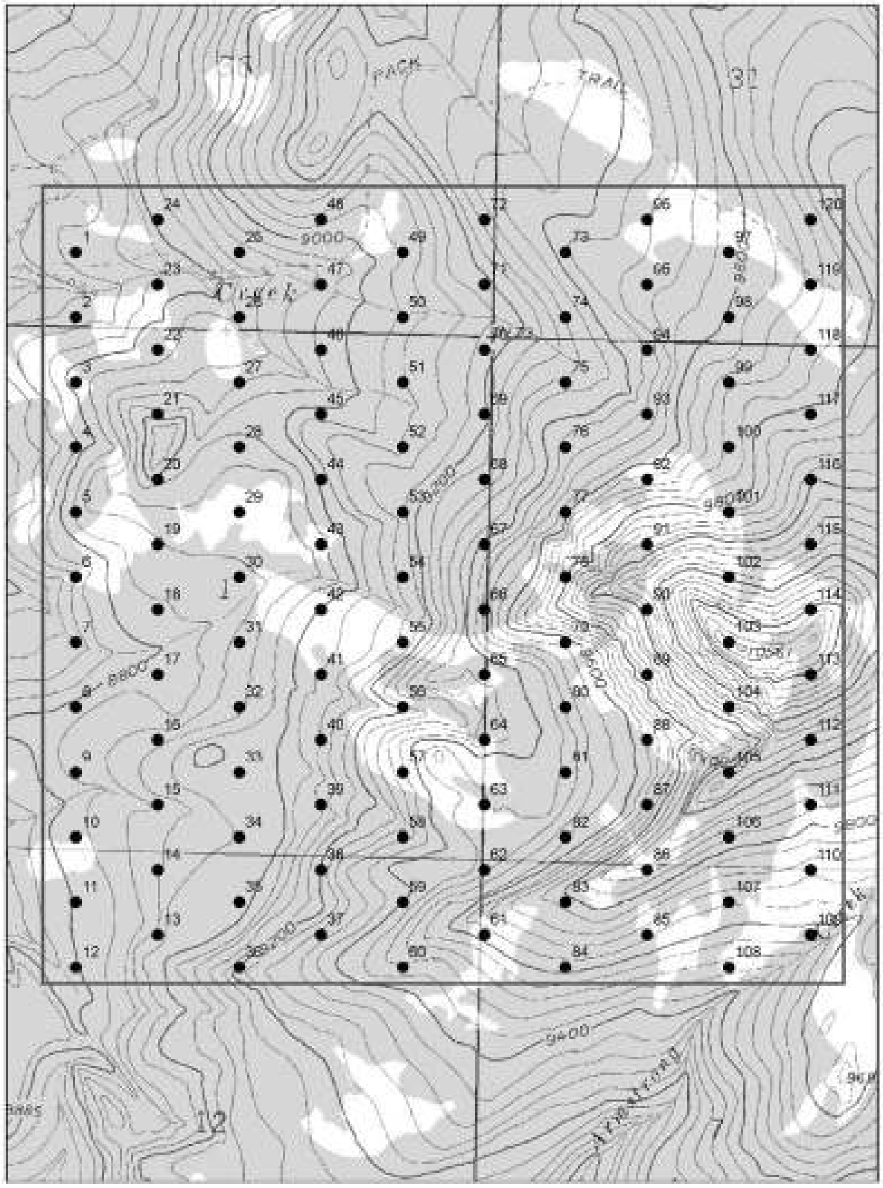


Figure 11. Sample PSU survey map, from Woodbridge and Hargis 2006.



Appendix 1. Northern Goshawk for Dawn Acoustical and Broadcast Acoustical Survey Protocols excerpted from Woodbridge and Hargis (2006).

Dawn Acoustical Surveys

1. Establishment of survey stations. Listening stations should be positioned within 150 m (meters) of all habitats to be surveyed. Use aerial photographs to determine point locations providing optimal coverage of suitable habitat within a radius of 150 m (7.1 ha [hectares]). To reduce attenuation of sound by surrounding vegetation or landforms, locate stations on slightly elevated positions, whenever possible, but not on ridges or in large openings. Efficiency may be increased by location of stations on roads; however, tradeoffs with position may occur within habitat patches. Stations must be clearly marked to allow for finding their location in darkness.
Whenever possible, establish multiple stations approximately 300 m apart to achieve simultaneous coverage of entire survey area by multiple observers.

2. Timing of surveys

Seasonal timing. To coincide with the peak of courtship vocalizations by goshawks at their nest sites, surveys should be conducted during the month preceding egg laying. Reproductive chronology likely varies between geographic regions and elevations, and local information should be used to estimate egg-laying dates. Backdating from estimated ages of nestlings can be used to determine reproductive chronology; use Boal (1994) to estimate
Northern Goshawk Inventory and Monitoring Technical Guide 3-7
ages of nestlings, and add 33 days incubation period. For example, if nestlings are typically 15 days old on June 15, surveys should be conducted in the area between March 15 and April 28. Note that during years with particularly cold or wet spring weather, onset of incubation may be delayed for up to 1 month.
If no detections of goshawks are heard during the first listening session, a repeat session should be conducted before May 1. Two sessions are required to assign "unoccupied" status to the area surveyed.

Session timing. The observer should arrive and be settled at the listening station *at least* 45 minutes before sunrise. The listening session should continue until 1½ hours after sunrise. Plan carefully so that the entire listening session can be conducted without interruptions for moving position, warming, eating, potty breaks, and other distractions.

3. Listening session methods. During each listening session, record start and stop time, actual sunrise onset, time and duration of goshawk vocalizations, type of goshawk vocalizations, and direction (bring compass) and estimated distance of goshawk vocalizations. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

Dewey and others (2003) reported a variety of calls detected during dawn acoustical surveys in Utah. Calls included variations of the alarm call (*kak-kak-kak*) (Squires and Reynolds 1997) and plaintive wail call (Squires and Reynolds 1997). Length of vocalizations varied from short, one-note call segments to series of alarm calls and wails lasting up to 10 seconds.

4. Locating nest sites. Auditory detection of goshawks during courtship indicates occupancy of the surveyed forest patch; subsequent location of the nest should not be attempted until after the estimated date of hatching. Intensive Search Surveys should be employed to locate nests.

5. Observer training. The principal requirement of this method is familiarity with vocalizations of goshawks and other species likely to be detected during surveys. Taped examples of goshawk alarm and wail calls, as well as vocalizations of the pileated woodpecker (*Dryocopus pileatus*), northern flicker (*Colaptes auratus*), sapsuckers (*Sphyrapicus spp*.), and Cooper's hawk (*Accipiter cooperii*) should be memorized and reviewed before conducting surveys.

An important aspect of Dawn Acoustical Surveys is observer transportation during early spring when snow conditions may limit access to many survey areas. Safety and logistical feasibility are important concerns when using snowmobiles and skis before sunrise, often in rugged terrain. Prior experience with forest carnivore, great gray owl (*Strix nebulosa*), and goshawk surveys has shown, however, that safe, efficient access is possible under these conditions, particularly if observers work in pairs. Training in snowmobile use, winter travel safety, and communications is essential for employment of this method.

Broadcast Acoustical Surveys

The protocol is based on the methods described by Kennedy and Stahlecker (1993), with refinements from Joy et al. (1994) and Watson et al. (1999). Adjustments to the number of surveys required and spacing of calling stations were made to optimize probability of detection and survey effort and cost.

1. Establishment of survey transects and stations. Before initiating surveys, use aerial photographs and topographic maps to determine optimal placement of survey transects. Draw detailed maps of survey routes and station location and provide them to crews conducting surveys. When possible, establish start and end points of transects along existing roads, trails, streams, or other landforms. The maximum distance between parallel transects should be 250 m. Minimize number of stations located on roads, unless roads are entirely within the habitat of interest.
Call stations should be located 200 m apart along each transect. To increase coverage, offset station locations on adjacent transects by 100 m. The most important factor in transect and station placement is completeness of coverage; to achieve acceptable confidence in survey results, all suitable habitat should be within 150 m of a calling station.

For project surveys, the survey area should include the proposed project area plus an additional buffer beyond the project boundary. For projects involving significant modification of forest structure (e.g., commercial thinning), the survey should extend 800 m beyond the project boundary. This distance corresponds to the mean radius of the postfledging area (about 200 ha) and will allow for detection of territories that overlap the project area. For projects that involve minor modification of forest structure (underburning, light underthinning, light salvage) surveys need extend only 400 m beyond the project boundary.

2. Timing of surveys. Surveys should be conducted during the nestling and fledgling stages, including early postfledging dependency. This period corresponds to June 1 to August 15 over much of the range of the northern goshawk. When possible, use

local information on nestling ages and dates to estimate hatching dates. After August 15, many fledgling goshawks will have moved out of the immediate vicinity of the nest stand, making location of the actual nest more difficult. Survey results might be unreliable after August 30. Surveys may begin half an hour before sunrise and should cease half an hour before sunset.

3. Calling procedure. At each calling station, broadcast at 60 degrees from the transect line for 10 seconds, then listen and watch for 30 seconds. Repeat this sequence two more times, rotating 120 degrees from the last broadcast. Repeat the three-call sequence again. After the last sequence, move to the next station. Move (walk) between stations at an easy pace, listening and watching carefully for goshawk calls and signs. The majority of time will be spent walking between stations, so it is important to be alert for goshawks approaching, often silently, to investigate the surveyor. Do not survey from vehicles or use vehicles to move between stations. Use of two observers will likely enhance the probability of visual detections of goshawks; however, experienced surveyors may conduct surveys singly (unless it is part of the bioregional monitoring design, in which case two surveyors is mandatory). To avoid misidentifying broadcasts of coworkers, simultaneous surveys should be conducted no closer than two transect widths apart.

• During the nestling stage, broadcast the adult alarm call.

• During the late nestling and fledgling stages, broadcast the juvenile begging or wail call. This call is more likely to elicit responses from juvenile goshawks.
Do not survey under conditions such as high winds (greater than 15 mph) or rain that may reduce ability to detect goshawk responses.

Record the detection type, compass bearing, station number, and distance from transect of any responses detected. Attempt to locate the goshawk visually and determine the sex and age (adult versus juvenile/fledgling) of the responding individual. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

4. Number of surveys. Surveys should be conducted at least twice during a given year. Detection rates of one-, two-, and three-visit surveys are given in table 3.1. Depending on the survey objective, surveys may need to be conducted during 2 consecutive years. See section 3.6 Survey Applications for discussion of multiyear surveys.

5. Equipment. Effective coverage of a survey area depends on the surveyor's ability to broadcast sound that can be detected at least 200 m from the source. Kennedy and Stahlecker (1993) and Fuller and Mosher (1987) recommend using equipment

producing at least 80 to 110 dB output at 1 m from the source. Regardless of the type of equipment used, broadcast goshawk calls should be audible at least 200 m from the calling station.

Until recently, the most commonly used broadcast equipment has been a small personal cassette player connected to a small megaphone. Recent developments include CDs and MP3 players as storage media and improved digital amplifiers that store goshawk calls on internal chips.

Other equipment required for surveys include compass, binoculars, flagging or other station markers, and self-sealing bags and labels for feathers and prey remains.

6. Preparation for survey. Study the appearance and typical flight patterns of goshawks and similar species before conducting surveys. Recent field guides should be consulted to review the field marks of male, female, and juvenile goshawks, as well as those of Cooper's hawks and red-tailed hawks (*Buteo jamaicensis*). Practice recognizing goshawks under field conditions before conducting surveys. Training sessions should include visits to a few known nests to enable survey personnel to develop familiarity with goshawk behavior and vocalizations. Identification of goshawk nests, plucking posts, feathers, whitewash patterns, and typical prey remains are also important aspects of survey preparation. The USDA Forest Service guide, *Feathers of Western Forest Raptors and Look-Alikes,* located on the CD inside the back cover of this technical guide, may be used to aid in identifying feathers collected during surveys.

Learn the typical vocalizations of goshawks and species with similar calls by listening to recorded examples. Examples of high-quality recordings of goshawks and sound-alikes are available from the Cornell Laboratory of Ornithology program, *Birds in Forested Landscapes,* and from the USDA Forest Service recording, *Voices of Western Forest Raptors*, included in the CD located inside the back cover of this technical guide. Field experience is important in learning to distinguish the vocalizations of goshawks from those of mimics such as gray jays (*Perisoreus canadensis*) and Steller's jays. These species are capable of producing excellent imitations of goshawk calls, particularly the female wail and juvenile begging call, and often respond to broadcast calls. Pileated woodpeckers, northern flickers, sapsuckers, and Cooper's hawks also have calls similar to those of goshawks.

7. Interpretation of goshawk responses. Surveyors should be aware of different types of responses likely to be encountered during surveys. Joy et al. (1994) classified responses into three categories: vocal nonapproach, silent approach, and vocal approach. The frequency of each response type varies between sexes, ages, nesting stage, and vocalization broadcasted.

• Vocal nonapproach—goshawks may respond by perching away from the surveyor, often at the nest, and vocalizing. This response is commonly elicited from older nestlings and juveniles as begging calls, in response to broadcast of either alarm or food-begging calls.

• Silent approach—goshawks, particularly adult males, will frequently fly silently in the direction of the surveyor to investigate and may be visible only briefly. Silent approach by female goshawks during the nestling and fledgling stages typically indicates an active nest within 200 m, but male responses may be long distances from the nest. Failure to detect this common response is a likely cause of false negative survey results.

• Vocal approach—commonly in response to broadcast of alarm calls, adult female goshawks (and, less often, males) frequently fly toward the surveyor while vocalizing alarm calls. This response typically indicates the active nest is within 200 m, particularly if the adult goshawk remains in the vicinity of the surveyor.

8. Locating active nests. Searches for active nests may be conducted immediately following goshawk detections (particularly vocal approaches or attacks); however, it is often necessary to review the results from multiple surveys and stations from a larger area to approximate the likely areas to search. Response type, distance and direction from transect, and distribution of habitat should be plotted on aerial photographs, and the Intensive Search Survey method should be employed.

Intensive Nest Search Survey

This method combines visual searches for signs of goshawk presence (nests, whitewash, prey remains, molted feathers) along closely spaced (20 to 30 m) transects (Reynolds 1982), with Broadcast Acoustical Surveys. Goshawk calls are broadcast along within-stand transects simultaneously while visual searches are taking place. This method is best applied to smaller units of area (4 to 40 ha), following stratification of habitat quality (Reynolds 1982, USDA Forest Service 2000).

1. Transect routes and coverage. Use aerial photographs and transportation maps to determine placement and direction of transects for optimal coverage of habitat to be surveyed. Determine compass bearing to be used in each survey. Number of observers (and simultaneous transects) is determined by size of habitat patch or unit to be surveyed; typically a minimum of three observers is required. Attempt to 'anchor' start and end points of transects on roads, trails, streams, or other features.

2. Timing of surveys. Intensive Search Surveys require presence of multiple observers within nesting habitat and are likely to cause excessive disturbance to breeding goshawks if conducted too early in the nesting period. Do not initiate surveys before the estimated hatching date.

The effectiveness of Intensive Search Surveys increases as the breeding season progresses, as nestling goshawks become more vocal, and as whitewash, molted adult feathers, and other signs accumulate in the vicinity of the nest. Intensive Search Surveys are most effective during late June through August. Searches may be conducted until snowfall; however, detections will increasingly depend on signs as adult and young goshawks move out of the nest area in the fall, and signs are lost due to precipitation and leaf fall.

3. Number of surveys. If conducted by experienced observers during late June, July, or August, a single Intensive Search Survey may be sufficient to determine goshawk presence within a habitat patch. If *any* sign of the presence of goshawks (feathers, old nests) is detected during searches, however, repeated surveys are necessary to determine nest core location (unless occupied territory status is assumed).
Data from Keane and Woodbridge (2002) indicate that single-visit detection rates obtained with this method are about 97 percent at goshawk sites with active nests, 73 percent at sites with occupied nonbreeding status, and 43 percent at unoccupied historical nest stands (table 3.1). If survey objectives require detection of sites with nonbreeding adults, then two visits are required to achieve detection rates greater than 90 percent.

4. Equipment needed. Broadcast system, self-sealing bags and labels, flagging, compass, and reference feather collection.

5. Conducting intensive searches. Following a predetermined compass bearing, observers should walk parallel transects spaced 20 to 30 m apart (30 m spacing may be used in open, tall-canopied stands where visibility is high). Mark the start point of each transect with individually marked flagging to allow retracing of the survey. The middle of the three observers should broadcast recorded goshawk vocalizations at points every 250 m along the transect, on every third transect line *(all observers follow procedure 3 under Broadcast Acoustical Survey).* Surveyors should attempt to maintain 250x250 m spacing of broadcast stations.

Searches should be conducted at a leisurely pace, allowing ample time for scanning the ground for signs, logs and low limbs for plucking sites, and *all* trees for nest structures. Any signs encountered (feathers, prey remains) should be collected in self-sealing bags labeled by transect location. Visual or auditory detections of goshawks should be recorded by transect location and detection type. Careful attention to the location of adjacent observers, especially the middle (broadcasting) observer, and to the compass bearing is important for maintaining consistent spacing of individual transects.

At the end of each individual transect, each observer should stop, flag the transect end point, and move to the start point of the next transect. If transects are directed back into the same habitat patch, the “hinge” or end observer should space the new transect no more than 20 m from the previous transect; this spacing reduces the potential of unsurveyed strips of habitat between transect groups. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

6. Postsurvey activity. After completing a survey, the observers’ notes, data forms, and collections should be immediately reviewed. Any collected feathers should be identified by comparison with reference samples. The USDA Forest Service guide, *Feathers of Western Forest Raptors and Look-Alikes,* located on the CD inside the back cover of this technical guide, can be used to aid in identifying feathers collected during surveys. Prey remains should be identified and the frequency of occurrence of each prey type should be assessed for each transect area. Any reports of whitewash and prey remains should be mapped, based on transect location notes. The entire area actually surveyed should be mapped.

Although whitewash and/or prey remains may indicate presence of other raptors, whitewash *and* remains of typical goshawk prey (e.g., snowshoe hare [*Lepus americanus*], Steller’s jay (*Cyanocitta stelleri*), northern flicker, and various species of grouse and tree squirrel) are suggestive of goshawk presence and trigger “possible

presence status” and followup survey of the suitable habitat surrounding (min. 300-m radius) the site. This need for a followup survey is particularly true if the initial survey was conducted early in the season, before July.

Because female goshawks molt during incubation and nest attendance, their molted flight feathers are typically found in the immediate vicinity of occupied nests. Male goshawks molt later in the season, and their feathers may be found over a larger area. Detection of goshawk feathers triggers “occupied status” and followup surveys of the suitable habitat surrounding the site (min. 300-m radius) to locate the active nest. If visual or auditory detection of a goshawk is made during an Intensive Search Survey *and* signs are present in the stand surveyed, the area should be considered occupied.

To locate the nest, followup surveys of the suitable habitat surrounding the site (300-m radius) should be conducted 1 to 2 weeks after the initial survey. Visual or auditory detection of a goshawk made during an Intensive Search Survey, *but with no signs encountered in the stand*, suggests that a nesting area may be located adjacent to the area searched. Broadcast Acoustical Surveys of the stand and adjacent stands should be conducted.

Appendix 2. Protocol for the determination of nesting activity and nesting productivity of Northern goshawk from the interpretation of field observations. Most information is excerpted from Woodbridge and Hargis (2006).

Breeding status is indicated by a nest that has supported a reproductive attempt in the current breeding year. Non-reproducing goshawks may reconstruct or add greenery to one or more nests during the courtship period; therefore, a determination of breeding requires evidence of egg laying. Direct evidence of egg laying includes observation of the following:

- Eggs (during climb to nest, from upslope, or with a mirror).
- Nestlings.
- Fledglings in the nest tree or nest area.

Indirect evidence of egg laying includes the following:

- Observation of adult female in incubation posture (sitting low on the nest, often barely visible) on 2 or more separate days.
- Presence of eggshell fragments below nest or near nest tree (fragments may be from failed eggs as well as after hatching).
- Presence of dime-sized nestling feces below the nest tree (typically found when nestlings are more than 4 days old).

Active nests are considered successful if one or more fledglings survive to the branching or fledging stage (more than 34 days old). Direct evidence of fledged young includes the following:

- Observation of one or more young goshawks judged to be at least 34 days old on nest or within the nest area.
- Auditory detection of more than one goshawk giving begging calls near a nest with signs of recent fledging (copious feces on ground, down on nest) after the usual fledging date (early July to August).

Indirect evidence of fledged young includes the following:

- Observation of an active nest with signs of recent fledging (copious feces on ground, down on nest, molted feathers, prey remains).
- Observation of remains of predated fledglings (more than 34 days old based on length of primary or tail feathers) in the nest area.

If nest checks are made while nestlings are younger than 34 days old, the nest may be classified as "active with young," but nest success remains unknown.

Accurate determination of the number of fledglings produced at goshawks nests is made difficult by the variability in fledging dates and behaviors of male and female fledglings. Male goshawks may leave the nest up to 10 days earlier than females, and fledglings may or may not return to the nest to roost and feed. Recently fledged goshawks are often lost to predation and are likely to be overlooked in fledgling counts. Simple counts of late-stage nestlings (28 to 34 days old) have the potential to miss early-fledging males or individuals laying down low in the nest cup, especially in larger broods. If productivity data are desired, it is preferable to use counts of large nestlings (24 to 30 days old) as a surrogate for actual number fledged. If counts are made from the ground (nest tree not climbed), they should be repeated at least once to increase the probability of detecting all individuals. At nests with limited visibility, such counts are unlikely to consistently provide accurate information.

Appendix 3. Goshawk territories selected for inclusion in the monitoring program.

Territory #	Territory Name	Rank For Monitoring		Comments
1	Angora 1	Burned	?	Will survey adjacent habitat to south, may be new territory
2	Angora 2	Burned	0	
3	Big Meadow	1	1	
4	Blackwood	2	1	
5	Bliss	1	1	
6	Burke Creek	2	1	
7	Burton	1	1	
8	Cascade	3	0	
9	Chamonix	1	1	
10	Cold Creek	2	1	
11	First Creek	3	0	
12	Griff	2	1	
13	Heavenly Ski Resort	1	1	
14	Hellhole	1	1	
15	High Meadows	1	1	
16	Incline	3	0	
17	Marlette Creek	3	0	
18	Martis Peak	2	1	
19	McFaul Creek	3	0	
20	Meeks Meadow	3	0	
21	Meiss	3	0	
22	North Canyon	3	0	
23	Page Meadows	3	0	
24	Saxon Creek	1	1	
25	Secret Harbor	2	1	
26	Sierra Creek	1	1	
27	Slaughterhouse	3	0	
28	Slaughterhouse Canyon	3	0	
29	Spring Creek	1	1	
30	Sugar Pine	1	1	
31	Tahoe City	Nest Cut Down		
32	Tahoe Mountain	1	1	
33	Tahoe Valley	3	0	
34	Trout Creek	3	0	
35	Upper Cold Creek	1	1	
36	Ward Canyon	3	0	
37	Watson Creek	1	1	
		# Territories Selected:	**20**	

Appendix 4. List and description of the associated files and GIS coverages.

To accessing files at the WO public ftp site through a web browser, type the following address into the web browser: ftp://ftp2.fs.fed.us/incoming/psw

Navigate through the following folder pathway to reach the files described below:

rsl/Slauson/LTB_Species_Monitoring/Goshawk/

Hex coverage This is the GIS shape file for the sampling hex boundaries.

Sample Unit Coverage This is the GIS shape file for the sampling unit boundaries.

Prioritization coverage This is the GIS shape file for the priority ranking for each sample unit.